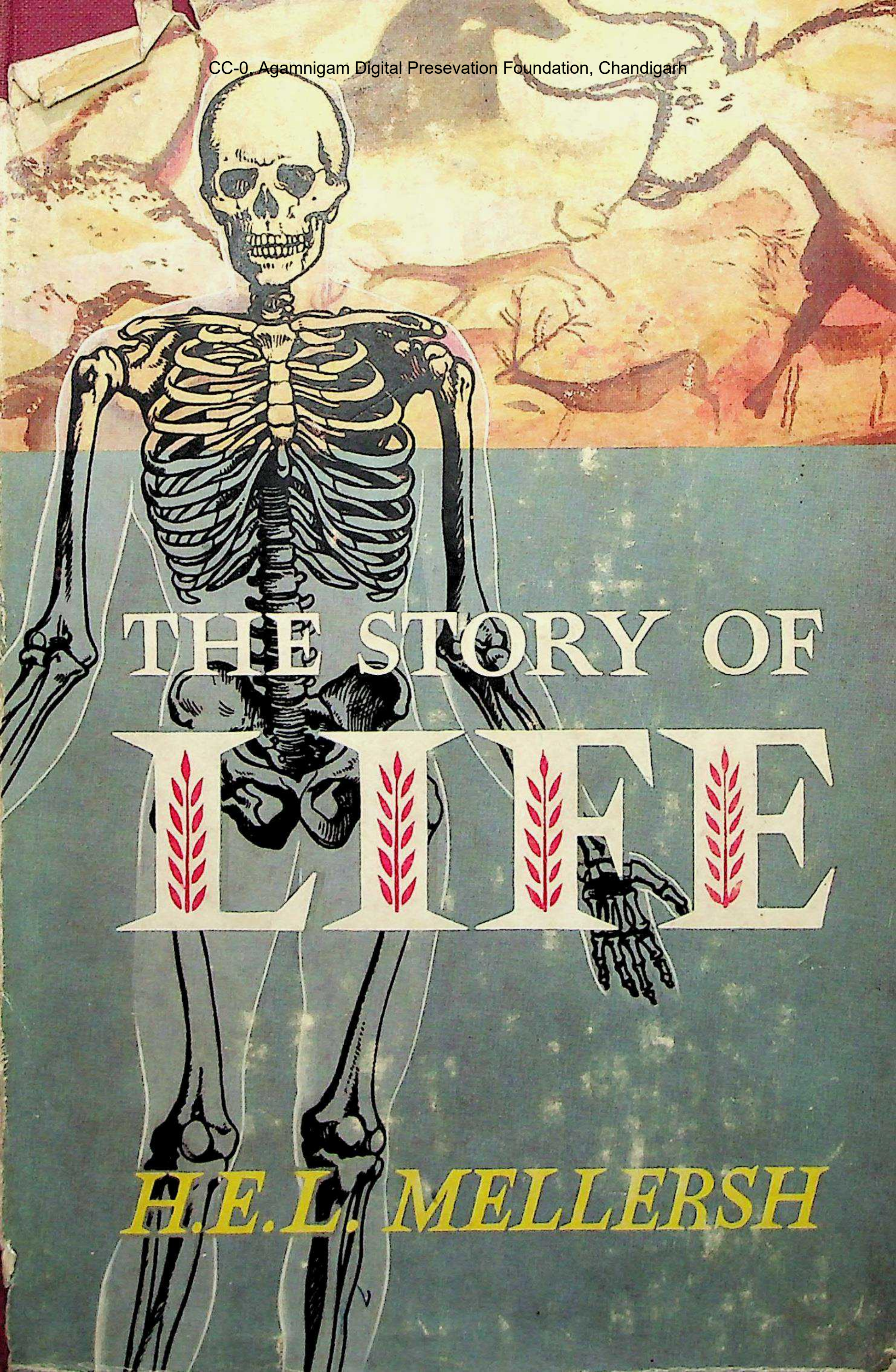

THE STORY OF LIFE

H.E.L. MELLERSH

Biology

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THE STORY OF LIFE

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The Story of Life

*

H. E. L. MELLERSH

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But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee:

Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee.

The Book of Job.

He prayeth well who loveth well,
Both Man and Bird and Beast.

S. T. COLERIDGE: *The Ancient Mariner*

Altruism as passion; that would seem as yet Nature's noblest product; the greatest contribution made by man to Life.

SIR CHARLES SHERRINGTON: *Man on His Nature.*

The birth both of the species and of the individual are equally parts of that grand sequence of events, which our minds refuse to accept as the result of blind chance.

CHARLES DARWIN: *The Descent of Man.*

CONTENTS

Page

INTRODUCTION 15

I. THE LIVELY AND THE LIVING 17

In which the unique property of life is traced in its progress as far as the nucleated and self-copying cell, an entity from some aspects simple, from some highly complicated, and from all fundamental.

II. IN THE COURTS OF THE SUN 26

In which the difference between the vegetable and animal kingdoms becomes slowly apparent and cells learn to co-operate and specialize—reaching in particular the pattern that possesses a head and a tail.

III. LIFE-BLOOD 38

In which we consider the effect upon life of changing climate and the evidence for the story of evolution to be found in the rocks, and proceed to trace life through to the creatures that possess blood, a heart and a segmented body.

IV. THE FISHLESS SEAS 47

In which, over the course of very many million years, life proliferates into a variety of patterns which thrive amongst and upon one another.

V. STREAMLINE 57

In which we observe develop the backbone and see life, while still in the waters, achieve appreciable increase in sensitivity and efficiency.

VI. THE TERRORS OF THE LAND 64

In which several kinds of life struggle away from dependence upon the waters and face a harsher but stimulating environment—to which they respond with exuberance.

Page

VII. THEY DO NOT FREEZE 77
In which the vertebrate stock achieves its greatest victory over changing environment, and again displays a disconcerting and misplaced exuberance.

VIII. THE PRIMROSE PATHS 89
In which we watch the mammals, for all their better brain and bodily efficiency, seek many comparatively unrewarding ways of over-specialization.

IX. WINGS AND INSTINCT 99
In which, leaving the general narrative for the more particular, we trace the evolution of the insects, their paying partnership with the flowers and their most peculiar kind of behaviour.

X. LIVING IN AMITY 107
In which a social way of life is developed at the expense of personality.

XI. BLITHE SPIRITS 123
In which some of the vertebrates develop wings without losing the use of their legs and conquer the air afresh.

XII. A BIRD'S LIFE 129
In which there is surveyed a way of life in which emotion finds full play.

XIII. PATTERN IN TIME 137
In which is traced the development of a kind of mind and behaviour that is often admirable, occasionally disastrous, and almost wholly different from our own.

XIV. THE OTHER PRIMATES 146
In which is traced the line of mammals that specialized the least and benefited in the process.

XV. PROMETHEUS UNCOVERED 157
In which the likelihood of men's physical ancestry is traced through the fossil discoveries, from tarsioid to the upright walkers of Africa and China.

Page

XVI. AND SO TO MAN 167
In which *Homo Sapiens*, the maker of tools, emerges from the Ice Ages.

XVII. SEX AND THE MEANING OF IT 173
In which, in a return to the main narrative, it is shown how even the more primitive forms of life have developed, out of a merely biologically useful process, some sensitivity and graciousness of behaviour.

XVIII. BRAIN AND THE USE OF IT 184
In which life's initial faculty of 'irritability' develops into its most wonderful instrument.

XIX. THE GROWTH OF LOVE 196
In which, by way of the not always admirable behaviour of the mammals and primates, there arrives the final triumph.

XX. SUCCESS AT ANY PRICE 206
In which are considered some of the least edifying and most stultifying successes of evolution.

XXI. THIS IS HEREDITY 213
In which we return to the single cell of life and its nucleus and consider what is known of the physical workings of heredity, whether of pea or fruitfly or man.

XXII. HOW DOES EVOLUTION WORK? 224
In which we at last look into the causes of evolution and learn of the views put forward by great minds from Aristotle to Darwin.

XXIII. THE ORTHODOX ANSWERS 233
In which currently correct explanations are given to questions that must arise, in particular how new species come into being and how something so apparently purposeless as natural selection can be held responsible for so much.

Page

XXIV. THE UNORTHODOX 245

In which the views of the modern unorthodox, sometimes called Neo-Lamarckians, are given, and the conceptions of function and pattern-in-time are recommended for consideration.

XXV. CONCLUSIONS 253

In which, though philosophy is eschewed, the soul and the mind are briefly considered, and the reader is gently exhorted to form his own opinions.

INDEX 257

ILLUSTRATIONS

(‘Evolution in Little’)

Between pages 112 and 113

Crinoid, typical of animal life that rooted itself to rocks more than 400 million years ago

Trilobite life. One 2½ in. long, a little above the average

Life branches off to perfect the pattern of the jointed limbed or arthrodpod. Two modern examples

The vertebrate arrives: the animal with the flexible backbone. A fossil and its reconstruction

Transformation of fins into legs. The modern mudhopper shows this rather well

A fossil amphibian, *Eryops*, just over five feet from tip to tail

Life leaves the water completely—and grows enormous. A dinosaur

Ascendency? Picture of a modern alligator devouring a frog

The argus pheasant, whose glory of plumage must govern his whole way of life

Fossil skeleton of a prehistoric giant tree sloth of South America

Marsupial wolf from Tasmania—rapidly becoming extinct

Caracal, specialist in ferocity

Ungulates, giraffe and kudu, gained fleetness of foot

The giraffe’s neck has caused a wealth of evolutionary argument

The elephant has, as it were, created a substitute for hands out of his proboscis

Two livers in trees, an English beech martin and a lesser panda

Reconstruction of an early Primate, a foretaste, a lemur-tarsier-monkey

Humanity

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LINE DRAWINGS IN THE TEXT

(*by Barbara and Dennis Young*)

Fig. *Page*

1. The beginning? 18
2. Amoeba 23
3. Volvox 29
4. Sponges 31
5. Hydra 34
6. Medusa 35
7. Planaria 37
8. Nereis 45
9. Mollusc and a mollusc shell 48
10. The head-footed 49
11. Nautiloids 50
12. Trilobite 51
13. Eurypterid 53
14. The Paleozoic seas 54
15. The Paleozoic seas 55
16. Amphioxus 59
17. Some early fish 60
18. Rhynia 67
19. The first legs? 70
20. Life climbs out of the water 71
21. Some of the giant saurians 73
22. More saurians—stegosaurus in the background 75
23. Enter the near-mammals 78
24. Conquerors of sea and air 80
25. Monotreme—the first milk-licker 82
26. Marsupial—baby grows in the pouch 83
27. Eo-eros? 86
28. Baluchithere 87
29. Be sorry for Syndoceras! 88

Fig.	*Page*
30. Mammalian specialists	95
31. The tarsier	97
32. The typical three-piece pattern of the insect—a hornet	100
33. Metamorphosis : the dragonfly	104
34. Ant carrying seed	113
35. Dairy farming	114
36. Ants	119
37. Archaeopteryx	125
38. A similarity of motion	127
39. A singing match	133
40. The gaping mouths are to be fed	135
41. Penguin ritual	141
42. Ruff to ruff, not ruff to reeve	144
43. The tree shrew	151
44. The lemur	152
45. The clownish orang utan	153
46. The sad chimpanzee	154
47. Contrast these skulls	155
48. Pelvis and stance	163
49. Skulls and brain-room	165
50. Neanderthal man	169
51. Hand axes	171
52. He ushers her in	182
53. The development of the brain	189
54. Lizards courting	198
55. The warmth of love	202
56. Sacculina on the job	209
57. Barnacle and young	210
58. The husband is marked with an x	211
59. The Abbé Mendel	215
60. The Crossing of the Round and Wrinkled Pea	220

Fig. *Page*
61. Lamarck 226
62. Life on the Galapagos Islands 231
63. Koala : tree-climbing marsupial 235
64. Does baby-in-a-bag make jumping more possible ? 236
65. Charles Darwin 240
66. J. H. Fabre 246
67. Function and form : the four conquests of the air 251
68. The birth of understanding 255

INTRODUCTION

This book is not a story of the 'discovery' of evolution but the story of evolution itself, of the gradual unfolding of life as it is believed to have occurred. There follows a review of the present beliefs as to the causes of organic evolution : not, you will observe, 'the causes' but the present beliefs that are held as to those causes. If the reader innocently imagines that so far as the theory of evolution is concerned there was first nothing, and then Darwin, and then nothing again, this book will at least disabuse him.

That in fact is largely why the book was written, because it seemed to me that there was such a great deal now known and thought about evolution of which the average layman was not only unaware but regrettably unaware—the regret being on his own side once he began to realize his deficiencies. So much of crude Darwinism, or the popular misinterpretation of Darwinism, is unlikeable—discouraging, sickening even—that about half of Natural History, I would say its more interesting half, remains a closed book to most people ; they have not cared to open it.

I hope, naturally, that people will care to open this book. I hope even that people who still say ruggedly that they do not believe in evolution will open it. Organic evolution is not a provable fact ; but as one biologist has said, with commendable restraint, it is a demonstrably likely proposition. Unfortunately not all biologists are restrained, nor for that matter are always their opponents. I have tried to keep a fair balance. If in any of these pages I have been rude to the Fundamentalist and the intuitive mystic, or rude to the more narrow, humourless or superior of the scientists, I apologize in advance : at least I do not mean to be rude.

The plan of the book is as follows. First is traced the general unfolding of life and then as the picture becomes diverse the line that leads to the mammals and man is followed. Then is picked up, for reasons that are made apparent, the lines that lead respectively to present-day insects and birds, with some enquiry into what rules their behaviour. There follows an attempt to trace the evolution of

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what might be called in one word sensitivity: the growth of intelligence, the sublimation of sex, the burgeoning of the emotions. Then, since this points so obviously to a culmination in man, there is a review, as up-to-date as possible, of what is now known and believed about human ancestry. Finally—after a salutary glance at the least likeable results of evolution and a necessary chapter on heredity—there comes the attempt to give a plain and unbiased exposition of what has been and is believed to be the causes of organic evolution and the force—or lack of force—behind it: through Lamarck, through Charles Darwin, to the present Neo Darwinians and the so-called Vitalists. The facts are given before opinions, so that the reader may be the better able to assess the opinions and in the process even remould his own.

Perhaps it is not fair to speak as if the first part of the book dealt with fact alone. The only facts in the business are the fossil records and the bodies, behaviour and growth of living things. Nevertheless, all those add up to a pretty weighty packet of evidence; and I have tried to present them fairly.

One word of warning. The language of this book will by no means always be strictly scientific: I hold that this is an advantage to which any book for the layman can claim a right. Nor should the scientifically minded fall into the trap of believing that though any mechanistic description or simile is allowable within reason, anything that smacks of the non-material is automatically suspect. This is Biology or the Science of Life; and life has properties that cannot be satisfactorily explained in material terms. However carefully I try to hold the balance between opposed views and rival interpretation, I do at least come down from the fence on that one point, the difference and the uniqueness of life. I cannot imagine that it is an outlook with which many people in the nineteen-fifties will quarrel, however much their great-grandfathers might have done so.

CHAPTER I

The Lively and the Living

WHAT matters to us about the Earth's beginning is how much of an accident it may have been. If it was the result of some normal process in the evolution of a star, or even of a few of the stars, then life is likely to be a thing extremely common in the Universe: even though it may exist only in some minute percentage of all space yet there will be millions of places where it does exist or has existed or will exist. But if on the other hand the planets of our sun were formed by some amazing cosmic chance, some collision or near collision less likely than that a monkey should type out a Shakespearean sonnet, then planets to a sun are indeed something extraordinary and, since planets of the right size and constitution are even rarer, life as we know it may be something quite phenomenally exceptional and even, as men have always liked to believe, unique.

It is irritating that such an important truth, affecting our whole philosophical outlook, is not known. For it certainly is not—any more than the beginning of the Universe is known or indeed whether it ever had a beginning. Only theories are propounded, often mutually destructive. Canon Georges Lemaitre, an astronomer and mathematician who certainly does not wish to muzzle enquiry, bids us be content to thank God in that we can 'recognize a glimpse of His glory in our universe'; and since these are the things that we can never know for certain perhaps we may well leave it simply at this: 'our sun formed planets'.

It is however a reasonable supposition that at the beginning the planets were incandescent. Very many millions of years, one would imagine, will have had to pass before our Earth would be in a fit state to receive life.

But how many millions of years does not matter very much. If we have no conception of how long the Universe existed before the forming of the Earth or for that matter whether the Universe ever did not exist, then there is little point in knowing how many millions of years had to pass before the fiery ball became the quiet sunlit globe of warm and shallow seas on which the birth of life became a possibility.

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What is of significance is that it is indeed a matter of millions. Do not let us be knowledgeably superior about this, saying nonchalantly that it was not merely millions but thousands of millions of years. For a million years is something breath-taking. We ought to approach the idea with humility and awe, and then spend a long time trying to appreciate the real significance of such numbers. William the Conqueror, 1066 : that is truly a great while ago. Do not deny it! Even if it is to us moderns a childish idea that it should represent something like the beginning of our history, yet it is a long time gone. Multiply by ten, and you reach back to the beginning of civilization. Multiply by ten again, and you are in paleolithic times, with Man as the primitive hunter. Multiply by ten once more, and you have reached at last beyond the beginnings of *Homo Sapiens* or perhaps of anything very like modern man—and only then have you reached a million years. Yet if you are a geologist or even a biologist you toss millions of years about as familiarly as a physicist tosses nuclear fission or an economist national debts. Trilobites, before they disappeared, reigned in the seas of the world for over a hundred million years; the well-nigh brainless giant saurians, changing slowly, proliferating laboriously as they laid their leathery eggs generation after generation to hatch in the unchanging and sultry sun, ruled the earth for nearly as long.

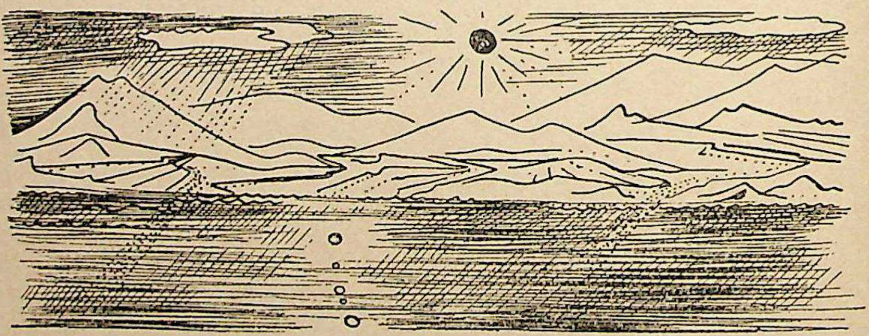

FIG. 1. The beginning?

The Earth—so it seems reasonable to believe—slowly grew fit through the millions of years to receive the beginnings of life. Its size changed, its rate of spinning changed, its distance from the sun changed. It probably accreted to itself much matter, perhaps other minor planets, having no doubt its days of super-cataclysm as well as its aeons of mere routine convulsions and eruptions and deluges and storms. Envelopes formed, of igneous rock, of water, of air; and as yet—at least one may assume—only one cycle remained constant, the colossal cycle of the whole galaxy of which the sun is a member turning like a catherine wheel through its majestic revolution.

Let us leave these awful figures and think about life and about its likely start in some humble and minute form.

To say that life's beginning could not happen again on this Earth seems like belittling the great achievement, like bringing down the master stroke of creation to a matter of seizing a lucky chance. But it is not so, for that is surely how life has always progressed, by taking its opportunity. One reason why life could not now so easily be created anew is that there has long been established a very real cycle of life, where the decay of one form is the building of another. More specifically, the armies of bacteria would attack before your embryonic life stuff, 'protoplasm', had had time to co-ordinate itself into anything beyond mere primeval jelly.

Nor is it necessarily a diminishing of God's works to envisage the possibility of man finally being able to create protoplasm in the laboratory. Jean Henri Fabre said the just word on this. He had been describing the gradual formation and unfolding of the fanlike wing of the grey locust. 'I have heard,' he said:

> 'I have heard that a learned inquirer, for whom life is only a conflict of physical and chemical forces, does not despair of one day obtaining artificially organizable matter—*protoplasm*, as the official jargon has it. If it were in my power I should hasten to satisfy this ambitious gentleman.
>
> But so be it: you have really prepared protoplasm. By force of meditation, profound study, minute care, impregnable patience, your desire is realized: you have extracted from your apparatus an albuminous slime, easily corruptible and stinking like the devil at the end of a few days: in short a nastiness. What are you going to do with it?
>
> Organize something? Will you give it the structure of a living edifice? Will you inject with a hypodermic syringe between two impalpable plates to obtain were it only the wing of a fly?

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> That is very much what the locust does. It injects its protoplasm between the two surfaces of an embryo organ, and the material forms a wing-cover, because it finds as guide the ideal archetype of which I spoke but now. It is controlled in the labyrinth of its course by a device anterior to the injection : anterior to the material itself.
>
> This archetype, the co-ordinator of forms ; this primordial regulator ; have you got it on the end of your syringe ? No ! Then throw away your product. Life will never spring from that chemical filth.'

So, to put this in rather a different way : if the first step of creating living, that is to say self-copying and self-renewing matter from dead matter was the greatest step, yet it was, one might say with respect, a step not very much greater in magnitude than many that had been taken beforehand—aye ! and that would need to be taken afterwards ere anything so incomprehensibly wonderful as an insect or a bird or a suckling mammal, let alone a thinking man, had been evolved.

To speak of steps taken beforehand may seem surprising. But there certainly must have been many, and they need to be considered. Julian Huxley, in his book *Evolution in Action*, divides the process into three phases, the last being what he calls, a little difficultly, the *psycho-social*, that is to say after Man has come upon the scene with his self-consciousness and his brain to direct the process, the middle being the *organic or biological*, and first the *inorganic or cosmological*. And to follow this last is to travel all the way from the empty spaces of random radiations, free electrons and 'stripped' atoms, which is said to be the normal state of the Universe, to a solid world of the most complicated molecules.

One does not need to know much Chemistry or Atomic Physics to appreciate something of the significance of that.

The elements which comprise all matter, living or dead, are all built up of that 'fundamental entity' the atom, rather as a house is built up of that fundamental entity the brick. But the atom of each element is different. And its two main characteristics of difference are the varying complexity of its structure and its comparative willingness or unwillingness to combine with the atoms of itself or other elements. (This last is rather as if one could not build a palace as opposed to a cottage with ordinary bricks but only with some marvellous combination of different bricks.)

Hydrogen and Helium possess the simplest atoms, and they are very common in outer space—comparatively speaking, that is to say, since there is by no means anything so common there as space. The sun sends out long flames of burning hydrogen; and the very name 'helium' denotes the same sun where the presence of the element was first discovered. In the sun's centre even helium and hydrogen cannot exist.

But, at the other end of the scale from this harsh simplicity, there must have come finally to exist on this earth the element carbon, the atom of which is not only complicated but, what is more important, has an amazing capacity—one would like to say 'desire' —to combine with other atoms, so as to make very intricate and varied patterns and chains and hence very complicated molecules. All that is in itself a great series of steps: to arrive from the electrically charged emptiness of space, through the furnace of the sun, to carbon chains floating peacefully in a sunlit sea.

Yet peacefully is not entirely the right word. There is that capacity of carbon—and of other elements for that matter, though in less outstanding a degree—to combine and re-combine, to form and re-form, to produce not indeed life but at least a very great liveliness, a progress towards increasingly intricate organization.

These warm shallow seas then, increasingly full of ever more complicated molecules, some as it were taking advantage of the others but none subject to the predaciousness of other forms of life: such is the picture. Then out of that there is created—not a living individual, not a living cell, nothing so complicated, but something that in the phrase already used is 'self-copying and self-perpetuating'. And sunlight—*light*—must have had very much to do with it.*

It is all too easy to become portentously mystical about light. It is equally foolish however to bar all intuition and imagination in these matters. How powerfully and strikingly the Bible opens:

> 'In the beginning God created the heaven and the earth.
>
> And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.
>
> And God said, Let there be light: and there was light.
>
> And God saw the light, that it was good: and God divided the light from the darkness.

---

* Lightning too, perhaps, so some recent experiments suggest.

5470

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And God called the light Day, and the darkness he called Night. And the evening and the morning were the first day.'

Without the atmosphere and the great size of our earth the sun's light and heat would not be diffused and reflected. If ever men travel out into space they will meet darkness and cold, with the sun and the planets shining out as orbs of clear-cut and inhuman brightness—that is the natural state of space, and one cannot imagine it supporting life. Our light and heat are the direct result, conveyed across a distance, of molecular and atomic and sub-atomic movement in the sun. To put it in a homely way, something happens in the sun, and across ninety-three million miles of nothingness something happens here as a result of it. The atoms of the earth are affected, and that in a way, do not let us pretend otherwise, that, however familiarly we may talk of electro-magnetic waves and photosynthesis and the like, we do not understand.

It is significant too that towards light the life of the world has responded by evolving the eye. One learns with surprise what simple forms of life do have eyes—eyes that is to say of a sort. Their owners will not see through them in a way that we understand seeing, for that matter they have not the brains wherewith to interpret. But they will nevertheless *respond* to light; those eyes will be there to help keep the creature by an automatic reaction floating the right side uppermost, or, even more fundamentally important, to keep it from sinking down into the dead, cold depths. Even the simplest one-celled life reacts to light.

Further than that, it is believed that protoplasm itself, that primeval life-stuff that Jean Henri Fabre challenged the scientists to make behave as God has made it behave, is sensitive to light—as indeed one would surely expect it to be.

So then to the true beginning: a world suffused with warmth and light; and in its seas the floating specks of the most complicated molecules, which are yet something more than molecules and have somehow increased their lifeless movements of attraction and repulsion and accumulation to the power to grow and split and repeat themselves as they lie bathed in the warmth and light of the sun.

But not yet a living cell. 'We can be reasonably sure,' says Julian Huxley, 'that . . . the earliest truly living things were nothing so elaborate as cells, but more in the nature of naked genes.'

And what is a gene, naked or otherwise?

This is admittedly slow progress, but there must be a pause while we consider what is implied by cells and genes. These things are fundamental. It is an extraordinary fact that there are living today many one-celled forms of life and that at the same time the bodies of men and plants and animals are themselves largely built up of cells that only differ in that they specialize to perform certain functions for the common good and do not lead an independent existence.

The cell is as much the fundamental brick of life as the atom is of inanimate nature—though to talk of either brick or cell can be misleading. The name was given because this lowest common denominator was first discovered in the study of plants, and there indeed it is boxed in and the name 'cell' is a good one. But the cells of our body, the white corpuscles or 'little bodies' of our blood for instance, are by no means neatly boxed; they are amorphous, restless, continually changing their shape. *Amoeba*, the simple one-celled animal that abounds in ditches and damp places and that is so like our white blood cells, moves in this way. It *oozes* over things. It feeds in the same way too, by oozing over things. It breathes, all over its body. It is no doubt very simple; but it is alive and does the basic things of life: it moves and so expends energy; it takes in food; it respires and so burns up this food with the aid of oxygen in order to produce its energy.

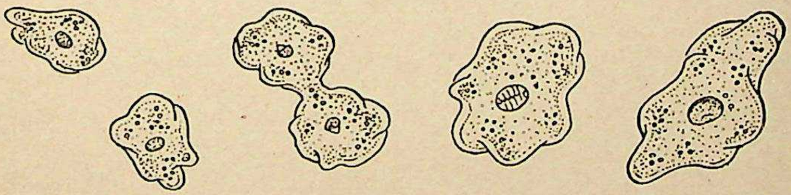

FIG. 2. Amoeba

It also perpetuates itself. It does so by the simple and drastic method of splitting into two. So do the cells in our blood-stream or in fact anywhere else in our body; so does the fertilized cell that starts a new life, be it vegetable, animal or human.

The process can be watched under the microscope: observing as it were the primeval birth pangs, the great act itself of 'self copying and self-renewing'—an act too of self-immolation, since what was one becomes two and there is no residue.

The creeping cell becomes quiescent. What has been its clearly defined 'heart' or globular centre, the all-important nucleus, stirs into activity. Faint grey granules appear. These come together to form a mass of thin threads. (Threads or chains of molecules seem the significant form in the beginnings of life.) Then the threads twist and wriggle until the mass looks, it has been said, like 'eels in a box'. Meanwhile the clear division between the nucleus and the rest of the cell disappears.

Next, the writhing slows down and the threads become shorter and thicker, to form stubby rods which are the *chromosomes*.* The chromosomes split in two down their length; one half of each pair thus formed goes dutifully to each end of the cell. There follows a sort of shivering climax all over the cell, 'like boiling pitch'; then a waist is formed in the cell, it grows thinner and thinner and into nothing, and the two halves separate and move apart as if mutually repelled. Each half proceeds to form a nucleus as a sort of bag round its own outfit of chomosome rods—and each half has thus become a complete cell to continue its life of slow oozing and feeding, until in turn its own time comes to split and lose whatever individuality it possesses as a sacrifice to the furtherance of its race.

Why this splitting apart and careful re-sharing of the chromosomes? They must be of great significance. The answer is, of course, that they are of immense significance and that in fact they carry the factors which govern the growth of the new cell and determine that it shall be a replica (or near replica) of the cell from which it came. Those factors are called the *genes* and are said to be 'strung along the chromsomes like beads on a wire'. They are physical entities—there is no reason to doubt that—but they are too small ever to have been seen through a microscope.

So we see that the gene is something extremely small yet with a capacity extremely great. We shall return to the gene in the chapters on heredity; all we need to appreciate now is that it seems to be the essential element in the renewal of all present-day life and therefore it is reasonable to suppose that it or something like it was the original progenitor of *all* life.

. . . . .

---

* Literally 'coloured bodies', that is to say bodies that take easily the stain for microscopic examination. Chemists are now finding themselves able to segregate and examine the 'nuclear acids' that form these chromosomes. They have a long name, conveniently shortened to 'D.N.A.', and their molecular structure and behaviour are strange and revealing.

What it comes to is this : although a single cell of life or a single-celled creature may seem to us something very simple it is nothing of the sort and evolution must have had a long way to go before it produced anything so complicated. How it did so nobody, rather obviously, knows. But at least this is a reasonable proposition : that over vast spans of time innumerable experiments must have been made, until the gene did indeed 'clothe itself' and with other genes become a one-celled creature.

The simplest one-celled creature alive today is, as we have said, amoeba. There is nothing unusual for some forms of life in the processes of Evolution to persist with very little change while others become extinct—we shall grow used to that idea—and even amoeba may be one of this kind.* If so, where there were seas, and where in fact there was any wetness on the so far quite barren land, there would be these microscopic, nearly transparent jelly-like creatures, about one-hundredth of an inch long, continually changing their shape as they slowly oozed along and showing within their glass-like body, precious and protected, the chromosome-containing, life-controlling nucleus.

Of life that has not reached the stage of the nucleated cell there remains today only slime, the shapeless moulds, the bacteria and the viruses. The virus is strangely like a naked gene, a gene gone wrong perhaps, parasitic or other forms of protein. For the rest, all that now lives is an elaboration of the first one-celled life : *proto-zoa.*

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* If you can cope with mathematical concepts, Sir Ronald Fisher's book, *The Genetical Theory of Natural Selection*, will give you an explanation of this habit of life sometimes to reach a 'stable equilibrium'.

CHAPTER II

In the Courts of the Sun

THE sea is a paradox. It is the cruel sea, not only to those who try to rule it, and it seems to impart something of its coldness and cruelty to the nature of those forms of life that inhabit it. Yet it is at the same time the least exacting home for life ; it is not for nothing that so many animals in the course of time have returned to the sea, reptiles in the shape of the extinct ichthyosaurs, 'fish-lizards', or the living turtle, mammals in the shape of seal and whale and porpoise. For, surrounded by water, life is safe from extremes : it cannot become desiccated and shrivelled by the bite of the wind or the heat of the sun ; it cannot, since there always remains water under the ice, become completely frozen. The world's life therefore not only starts in the waters but for millions of years is to be found nowhere else but in the waters ; at most it will climb out on to the edge, but there it will be inexorably limited by an invisible barrier that is the line beyond which the merciful tide does not return to lave and succour and assuage.

Yet how far life has to travel before it can even take that early step to the often warm but always dangerous paradise of the sea shore ! The single-celled life is indeed a miracle. But as yet : no blood, no nerves, no sex, no head, no brain.

Now that which moves and grows expends energy, and to be able to do so it must be supplied with fuel, which we call food. The taking in and the using up of food, what as most schoolboys know is called ingestion and respiration, is in fact very much the same process as burning : the harnessing of oxygen for the purpose of releasing heat or energy. And, just as everything will not burn, so—indeed even more so—everything cannot be ingested. As Christopher Robin's Tigger found by painful experience, everything is not good to eat. In that world of embryo life very few things must have been good to eat, that is to say to absorb. And it is perhaps not surprising to find that just as life was not possible until the most complicated molecules were evolved, so also it is only these most complicated molecules that can be used as food. Life needed what the dieticians are still telling us we need : carbohydrates and proteins. How was it to get them ?

There were really only two ways: to manufacture it, or to batten on the manufacturer; to feed in fact as the plant feeds now or as the animal feeds now. And the kind of life that manufactured its own food must have invented *chlorophyll*.

Nowadays we put chlorophyll into tablets and toothpastes; it would be hardly less gullible and much more proper to worship it—indeed one might say that our primitive ancestors when they worshipped the sun did worship it. For chlorophyll is made possible by the light of the sun; it is the green constituent of plants, by which light, water and the carbondioxide in the air are compounded into carbohydrates; it is the great catalyst, the key that unlocks the power of the sun—the axis on which the life of our world turns.

Were, then, the first forms of life virtually plants, having chlorophyll? On the face of it they must have been. But this the scientists tell us is not necessarily so. For experiments have shown that light acting on certain simple chemical compounds can produce slight traces of sugar and other organic matter without the aid of chlorophyll; perhaps then this was how the first protoplasm came into existence, and perhaps the first properly integrated one-celled creature lived off this same protoplasm. Nevertheless the important thing to realize is that, if there was to be any progress, the split—the split between living off the sun and living off those that lived off the sun—had to be made and in fact must have been made very early in the history of life. This is by no means the same thing as saying that there was at so early a stage a split between life as plants and life as animals, since things are as yet much too embryonic for any such distinction to have any real meaning.

There are creatures still existing that illustrate admirably this lack of a clean-cut dividing line, taking on as they do, and as it were quite casually, either a vegetable or an animal attribute. They are a kind of *flagellate* called Euglena and belonging to the same phylum or division of life as amoeba.* This microscopic creature while remaining otherwise practically identical sometimes produces chlorophyll to help in this livelihood and sometimes does not.

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* The phylum concerned is *Protozoa*, Greek for 'First Life'. This is an opportunity to explain shortly the accepted divisions of life, for the reader of almost any work on biology will be lost without some knowledge of them. The *species* is the basic division, roughly the kind of animal that can interbreed. The next higher group is the *genus* (plural *genera*, Greek for, shall we say, 'kin'): as we would say a dog differs from a fox. Next, *family*: dog tribe as opposed to cat tribe. Next, *order*: carnivore as opposed to insectivore or—to bring in ourselves—to primate. Next, *class*: mammal as opposed to fish or reptile or amphibian. Next, *phylum* (Greek for 'stock' or 'race'): vertebrate as opposed to arthropod; or for that matter to protozoa as above—one is concerned here with the whole pattern or 'ground plan' of the animal. And finally *kingdom*: animal as opposed to vegetable.

And it seems reasonable to regard these flagellates as the probable next step in life's progress. For they are so much more *mobile* than the amoeba—who, in order to move, clumsily and temporarily creates a pseudopod or false foot out of its own shape, takes a slow leap over that foot, and then either stays still or gradually forms another pseudopod. The flagellate on the other hand has his whip or *flagella*, a long hair-like strand—there may be up to four of them—which it lashes to and fro in the water for the very same purpose that the lone fisherman waggles an oar at the back of his boat.

Hairs waving in the water to form a current are in fact a great early invention on the part of Nature. They may be short and many, usually called *cilia*, or few and long when they are *flagellae*; they cause eddies in the water either away from their owner which will cause it to move, or through their owner, which will help supply it with sustenance. There are even one-celled cilliates in our own body, in our own throat and nasal passages for instance, which keep a liquid in motion for the good of the larger entity.

Now one-celled life can be very varied. Our modern ponds and ditches and rivers and seas still teem with one-celled life, amoeba, flagellate, and ingenious and often beautiful microscopic creatures called diatoms that have formed themselves a shell of silicate; and many such as these, together with less successful experiments, may have lived in the early seas. But to ring the changes on a single cell has obvious limitations. Life, even though it has achieved some mobility and the power to choose between living off the light of the sun or off its fellows, has got to do something much more drastic and difficult if it is going to progress. It has to increase in complexity, and for that it has to increase in size.

Since the size and complexity of any one-celled form of life is strictly limited the only practical method of growth was for a *many-celled* form of life to be created. The most obvious way for that to happen was for many one-celled creatures either to stay together at birth, that is to say at the time of splitting and resplitting, or to come together later, and by a sacrifice of some of their independence to create a new and larger individual.

As with Euglena there exists a living example of this. It is Volvox, a small green ball about a fifteenth of an inch in diameter which is to be found in streams and ponds. It is made up of a thousand or so green flagellates, each with a couple of whip lashes apiece. But those whip lashes *do not work against each other*—the creature would never have survived if they had. There comes in fact the beginnings of co-ordination and specialization. The flagellae lash in unison and the creature, in spite of being a mere ball, has a front and a back end. Not only that, but the front flagellates have the rudimentary light-sensitive eye-spot that some of their free and unattached relatives possess, and as for the back members, only they have the power to reproduce their kind.

And yet even the thousand-cell volvox is remarkably small. We human beings are giants in our world : it is worth realizing how much of life still is, and certainly was, so small as hardly to attract our notice at all; millions of years after the creation of life a not very observant eye-witness, sent shall we say from Mars, might well have reported back that the World was still uninhabited.

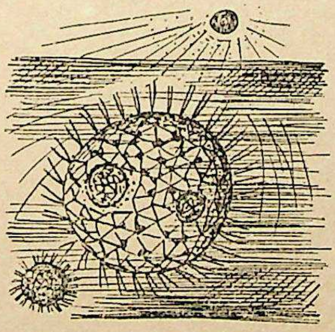

FIG. 3. Volvox

The first really sizable objects of the sea were probably the seaweeds and the sponges. Plants we will leave until we come to the time where life emerged from the waters on to the dry land. But the sponge —poor sessile brute that it is—must be classed as an animal. It starts life as an active flagellate ; but soon it settles down, literally, and lives by beating currents of water through itself and feeding upon what digestible organic matter there is in the currents.

The sponge is in fact a collection of specialized flagellates beating inwards together, with one large funnel for the water's egress. It also specializes some of its cells to secrete an inner skeleton of lime or flint or horn, and so it has a support round which to grow and to grow big.

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Nevertheless, sponge is really a very primitive animal. If hurt it can, by means of muscle cells, retract. But it only retracts *where* hurt. It has no connecting links of response: it has no nerves. It can do something rather extraordinary, however. Press a live sponge through fine silk and the cells come through singly or in very small groups. Leave these in a dish of seawater and they will creep about amoeba-fashion and when they meet they will join until there are a number of small masses, which then proceed to grow into new sponges.

Now this surely is a most amazing thing to be able to do. It is a power of *regeneration* that many forms of life possess, but none in such a striking degree. We ourselves can do no more than heal a wound or grow a finger-nail; in fact the power seems possessed by forms of life in inverse ratio to their complication: beyond a certain point the regeneration becomes too difficult. But the great wonder of it is that the faculty should be possessed by life at all. It is, after the creation of the self-copying cell, life's second great miracle. The cell knows how to grow; but the colony of cells knows how to combine and then how to acquiesce in specialization and divisions of labour, so that a greater entity, a higher individual, is formed—and not only that, but so great is the urge for combination that the cells when forcibly parted will come together again to merge their autonomy under the greater government. Were it not that it would certainly be misinterpreted, the United Nations Organization might well have the sponge for its symbol.

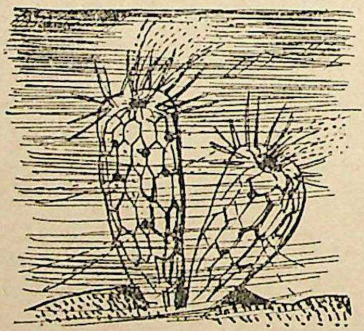

FIG. 4. Sponges

Let us proceed with the story. The animal next to be contemplated is the kind that evolved nerves; the next, a head; the next, blood.

This however is likely to prove confusing. What is difficult to realize is how a life can function at all that does not eat as we understand eating, and that possesses neither head nor heart nor any of the sensitivities and responses the lack of which in us would lead us to count ourselves as virtually dead. The connection between our own very complicated life-activities and those embryonic ones which begin life's story need to be explained.

First feeding and digesting, that is the taking in of food and the breaking of it down into fuel that can be oxidized and turned into energy. The great primitive way in the waters is to take all and choose what is good in it, to waft a current inwards by means of rhythmically beating hairs or tentacles and to strain out what is edible. Even a species of whale does much the same; and many of the present-day single-celled animals do it too. The amoeba however, and presumably its primitive counterpart, having no hairs, cannot. Instead, and as we have said, it eats in the same way as it walks: it extends a part of its protean body into what is called a 'pseudopod' or false foot, and envelops the infinitesimal form of life that it has marked down as its prey. There the speck of life will remain in what is called a food vacuole, and there it will very slowly be digested, the residue being discarded, or rather, in this simple method of eating—or walking—left behind.

But what is this 'digestion', and how is it done? We have already used the word 'breaking down', and that is probably the best description of it. In man and mammals the process starts in the mouth and goes in a variety of ways right through the digestive tract. In Wells' and Huxley's *Science of Life**—a comprehensive book of popular biology to which this will not be by any means the last reference—this has been likened to the assembly line in a motor-car factory working in reverse, 'a chain of chemical workmen' carefully and methodically pulling the thing to bits. These workmen are called enzymes and they are themselves chemical substances secreted by the body specially for the job—*solvents* they might be called and in molecular construction they are about as complicated as the organic molecules they break down.

In primitive life very much the same thing happens. Even the amoeba, it is believed, produces enzymes; the great difference between man and amoeba is that the latter can digest anywhere apparently within its microscopic body, as in fact it can perform

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* By H. G. Wells, Julian Huxley and C. P. Wells.

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most of its small repertoire of functions. The difficulty comes with size. The sponge possesses amoeba-like cells that *creep about* its body and complete the digestive process begun by those cells at the surface that waft the food inwards with their cilia. In other words specialization begins to increase with complexity. But the essential process is always the same : engulfing the food, breaking it down by means of enzymes, and then getting rid of the residue.

With an equally startling simplicity does primitive life respire or take in and make use of oxygen. We complicated air-breathing creatures look upon lungs and blood and heart as necessities. But that is not so. The best way, I think, to realize how simple oxygenization can be is to appreciate that our own elaborate system depends on two elementary properties: *closeness* and *dampness*. This may sound strange. But our own system, of introducing oxygen to all parts of the body, does depend essentially upon producing a great area, always wet, where the oxygen can as it were ooze across, first from the lungs to the blood and then from the blood, by means of the lymph, to our tissues.

Go then to the other extreme, to the amoeba, and there is on that basis hardly any problem at all. The oxygen is in the water, the body is so small that no transport system is necessary : the oxygen simply *diffuses* into the amoeba as required. And in the sponge it is no more complicated, except that a current of water is wafted through all the time. Salt water is, indeed, primitive life's blood-system—which makes the facts that our own blood is in bulk largely salt water, and that pumping such water into our wounded system is often the next best thing to pumping blood, matters of some relevance and significance.

Lastly in this business of seeing how primitive life functions and to connect up with our own, there is the whole business of response and sensitivity. That is of the greatest importance, for in the increasing range and speed and subtlety of an animal's responses to its environment lies its chance of success.

How then is one-celled life, that is blind and deaf and indeed seems lacking in all of what men know as the five senses, able to survive ?

The answer is in one word, a word used in a particular and technical sense and used, too, as must be so many in science, to define a phenomenon which we can recognize but not explain. That word is 'irritability'. It obviously has no connection with bad temper.

'Excitability' is another word sometimes used in its place, and again not the characteristic of the human young. It is a property of the simplest life, and presumably of protoplasm itself, to respond in a slow way to outside stimuli, of light, of touch, and of chemical constituent. Thus it is possible to 'tease' the simplest forms of life by putting unpleasant chemicals in the water they live in, by touching them, and by subjecting them to too strong a light. In response they shrink, and take avoiding action.

It is something like this that one would surely expect to happen. Without this elementary irritability and power to respond, life could neither have survived nor progressed. The heart of the matter is this: the first cell is all things; then as cells combine to form larger life they specialize to make more—much more—of one or other of their little repertoire of abilities. One kind will become increasingly sensitive to light, until the miracle of the eye is formed; another will specialize in reproduction, until mere splitting becomes sex; another will multiply a thousandfold in efficiency the power to pass on a stimulus, and—perhaps the most significant transformation of all—will grow into that live and tenuous thread, a nerve.

And as yet, under our examination, life has only reached the sponge, an animal so unresponsive and immobile that it is less than a century since men were convinced that it was an animal at all. The sponge is in actuality a dead-end, an early and clumsy experiment at co-ordination; yet it survived, and survives to this day, perhaps largely because a sponge hurts nobody and nobody wants to hurt or eat a sponge.

Jelly-fish come next in the story, or rather the phylum of *coelenterates*, which has as its modern representatives the jelly-fishes, the sea anemones, the corals, and the tiny fresh-water, stinging hydra.

Coelenterate means 'hollow guts'. In other words, here is a form of life that has achieved something better than the digesting ameoboids of the sponge wandering slowly round the labyrinth of the body. This kind of animal has a special place for digesting—and it connects itself with the outer world, by a mouth.

It also has a concentration of something special round that mouth. The microscopic current-wafting cilia have become tentacles—tentacles that can wave restlessly, and seize, and sting, and pass the prey into the waiting hole. These are not pleasant habits, but they are an undoubted increase in efficiency on the part of their owner.

These creatures have not been even given pleasant names, though picturesque enough. The two most common forms have been called respectively Medusa and Hydra, both because of these writhing tentacles that made the early naturalists think of the snakes around the Gorgon's head or of the many-headed serpent that worried Hercules. Medusa is the pulsing, round jelly-fish—it may be huge or merely microscopic—and Hydra is the stalked, flower-like form rooted to the rock on the bed of stream or ocean. Some of the coelenterates will take one form and some the other—and many in their lifetime will take both. Medusa and Hydra (or more generally, Polyp) are in fact different forms in the life cycle of these creatures, and if a particular species only appears in one of these forms the assumption is that in the course of time it has lost the other. Coelenterates illustrate that habit of so many varieties of life, of going through a cycle of quite different forms. Probably it also illustrates another habit of life, the habit of lapsing into a simpler and lazier form that sits down and stays put : for it is believed—a rather pleasant

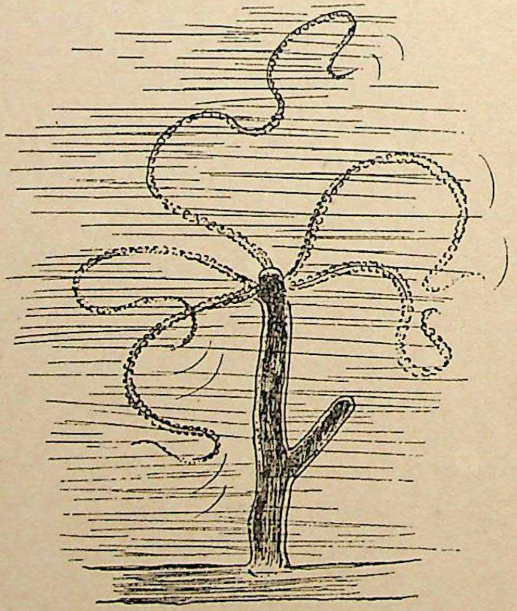

FIG. 5. Hydra

belief—that the first coelenterate was of the active and free-swimming kind.

It is this swimming that is important. The amoeba oozes, the flagellate lashes a pair or so of flimsy hairs; but the medusa, the jelly-fish, pulses its whole body. For this it needs a ring of muscles. It also needs muscles to manipulate the tentacles round its mouth, and at the same time a reasonable approach to quickness in response. The slowly passed-on irritability of the embryonic cell-colonies and their equally slow powers of reaction are not enough. There arrives with the jelly-fish, primitive though the creature may seem, the next great step: the nerve. The coelenterates have a network of nerve-cells, that is to say cells that have both immensely elongated themselves and increased their powers to convey irritability; they have them all over their bodies.

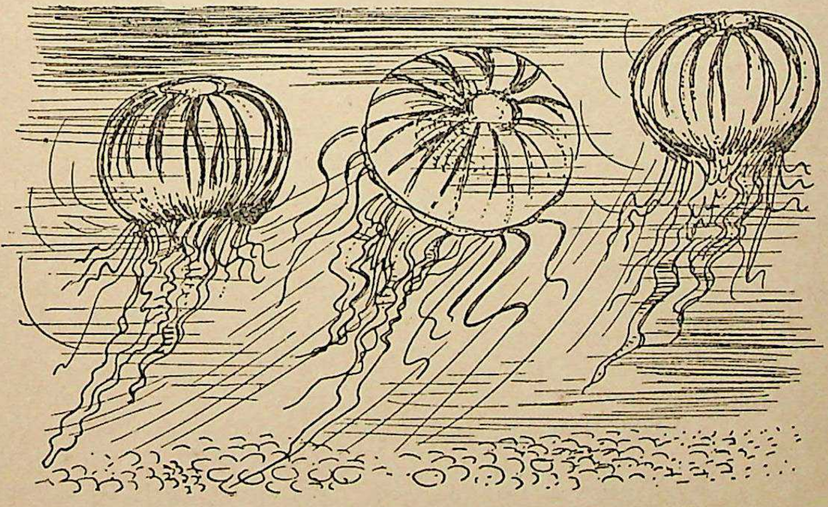

FIG. 6. Medusa

Further than that: this new important feature, the mouth, has a closer network of nerves around it than has any other part of the body. There, in fact, is faintly foreshadowed the brain and the head.

Yet how faintly as yet is it foreshadowed! The coelenterate emphatically has neither head nor brains; it has only, one might say, a stomach. That and a network of nerves. There is no co-ordination or centralization about those nerves; it is like a telephone system without an exchange, anywhere ringing everywhere. Nevertheless it is an advance: place a finger-tip in the tendril-surrounded mouth of a sea anemone, and observe how quick is the response.

The next successful elaboration is going to be a matter of shape, of body-pattern. A jelly-fish can swim, up and down that is to say, pulsing itself upwards and then letting itself fall slowly, with luck on top of some food. It can grow long viciously stinging trailers; by the aid of its amorphous jelly it can grow to a great size; it has even, in the shape of the 'Portuguese Man-o'-War', learnt to grow a sail of sorts with which to catch the wind above the waters. But unlike the lover in the song it does not know in the least where it is going. For that you need a front and a back end and at the front end a concentration of your sensitivity. *A worm* has all this.

The worms are a large and varied group, successful in adapting themselves to many environments, though this success men can hardly look upon with favour since the environment is sometimes their own or their domestic animals' bodies: the worm is in fact an animal neither so lowly nor so primitive as its name somehow seems to imply. Its kinds are divided by the scientists into three, round, flat and segmented; and it is the flat kind that, for reasons that will soon become apparent, are believed to have arrived first on the evolutionary scene.

Planaria is the most commonly known modern flat-worm. It is a half-inch of black ribbon with an arrow-shaped head, two well-marked 'eyes' (that do not see but tell the animal where light is), an obliging habit of regenerating itself in queer and revealing ways when carved up by the serious army of experimenters, and a nervous *system*.

The key word here is 'system'. A sponge is a colony of cells in which the cells have begun to specialize; a jelly-fish possesses 'tissue', or associations of cells of the same kind that work together to perform a common function—muscle for instance or the nerve net of which we have spoke. But with flat worms we come to the third stage, where tissues of cells work together in even closer harmony to form an 'organ' and to function as a system. Flat-worm has a digestive system, an excretory system, a reproductive system, and a nervous system. These are certainly most primitive compared with man's, but they are there. And the nervous system is something much better than a mere network of nerves and may even be said to include the beginnings of a brain.

Yet, again, how primitive and how far from mammalian brain, let alone man's, is the brain of the flat-worm! It is a double lobe in its head, the culmination of a ladder-like structure of nerves that extends symmetrically down its body. But the creature does receive sensory impressions in this one central place, and with it the creature does *direct*. A planaria is not pulsating aimlessly or waving optimistic tendrils around its mouth. It seeks its food—and finds it. Place a piece of raw meat in a stream and if there are planaria there it will soon be covered by them. Their sensitiveness to the chemical constituence of the water has been conveyed to their primitive lobes of brain, and brain has directed their means of locomotion—they have both cilia and muscle—to convey the body to the right place.

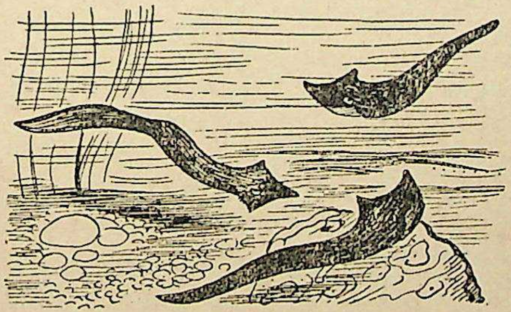

FIG. 7. Planaria

Nor will the journey take very long. For the flat-worm has attained in its body pattern *bilateral symmetry*, a head and a tail and a top and a bottom. It is a pattern that is remarkably efficient in, amongst other things, speed of movement.

Yet in this new form of life, with head and tail, something more is needed than bilateral symmetry : it is what we may justly call good thoroughgoing solidity, the advantage of possessing with no shadow of doubt three dimensions. The coelenterate bulked itself out with air or jelly ; the flat-worm is very flat, it had to be. They both lack something which we possess and which rightly we have always regarded as symbolic of life, because life—animal life that is to say—has never progressed very far without it. What made this disciplined solidity possible we will reserve for the next chapter.

CHAPTER III

Life-blood

WHY should life have changed at all? Why, in the sunlit primeval seas should it not have gone on proliferating gently and evenly and conservatively, unicellular life splitting and resplitting and perpetuating itself ad infinitum?

That is a reasonable question. A reasonable answer is to say that God did not will it so—and we might surely add without disrespect that we can hardly imagine that God would will it so. But that does not help us very much to understand. It is perhaps a more illuminating answer to say that life, from all the observations we ever make of it, and indeed from a most superficial observation of it, does seem always to *take its opportunity*. It presses; it surges forward; it fills finally every nook and cranny and every habitat. Not only that but it seems to struggle to fill the habitat as efficiently as possible; if the habitat does not change then it will change itself to fit the habitat.

But the habitat, the environment, *does* change: that is the important point which must be realized before we proceed any further. So far we have seen life advance from the single cell into the colony of cells and then into a colony of greater specialization and division of labour amongst its cells so that it may be said to become more than a mere colony, in fact an embryonic individual; we have seen the seas blossoming forth—and at times it is almost like a flowering—into those forms of life that still exist and that often seem to us most beautiful in form, the sponges and the coelenterates—hydra, sea anemones, sea lilies, jelly-fish—pulsing and swaying in a slow and gentle rhythm. All that happened, it seems, through millions of years in the favourable environment of warm and shallow seas. Life was as it were making leeway, reaching a minimum of efficiency and variety. But at some time or other, and inevitably, two things would happen: competition between one form of life and another to fill the existing environment, and changes in that environment that would have to be met. By the time we reach the end of this chapter, when not only worms but life with shells and life with armour will be arriving, we shall be witnessing this competition and these changes come into play.

The great changes in form and climate that the earth's surface has suffered since it cooled down into some sort of stability were hardly suspected a century or so ago : it is a tale patiently brought to light by the geologists. The details of this story may be arguable; the causes of the changes most certainly are arguable. But it is at least common sense to realize that a ball hung delicately at just the distance that makes life possible from a colossal fiery furnace pulsating with light and heat and disintegrating atoms is not likely to go on its way through the millions of its gyrations in an entirely equable manner. It is common knowledge that Man suffered in the infancy of his race from great Ice Ages, that on the other hand the same lands, including our own, that suffered the glaciers had equally supported the tropical tiger and hippopotamus. But these changes, startling as they are, are recent changes ; in the great age of the earth they are as it were the minor shudders and sweatings of a patient who once a year has a bout of influenza. That is indeed not altogether a fanciful simile, because these terrestrial changes do seem to come at definite intervals, they do seem to come in *rhythms.*

The main rhythm seems in fact to be a colossal span of something like two hundred million years. Nobody knows the reason, though it has been suggested that in that period the galaxy or 'island universe' of which our sun is a member turns once on its axis. It runs something like this. First, there is a 'revolution', an outburst of mountain building that pushes the land upwards and collects the seas into great and deep pockets, and then a slow and gradual changing to the opposite that settles down into a long period of tranquillity and warmth and shallow seas, where the amount of dry land may be no more than half what it was at the time of maximum emergence. The times of revolution will be times of great cold and aridity ; and the gradual changing to the opposite will be punctuated by fluctuations in the cold and in the dryness that will themselves no doubt seem never-ending to the life that suffers them.

That is the outline of the story. And these periods of violent change, whether major or minor, will obviously be a most trying time for life, a challenge, in fact, to which some forms will succumb and others will respond triumphantly. One thing however we must realize at this stage : the effect of these changes will be much more apparent in the later part of life's story. It is not only that being more recent we can decipher their effects more clearly, but also that the sea as a home for life is as we have already suggested a kind and protective home, and while life was still wholly in the waters the worst of the world's shocks were presumably damped down for it.

There is now something else that we must consider carefully before we continue with the evolutionary story.

What is the *evidence* for the story? The answer is that by far the most important evidence is given by the fossilized remains found in the sedimentary rocks of the world's surface. Once again it is only in the last century or so that the geologists have given us the clues. But, the acute reader may point out, there has been no reference whatever to fossil evidence in the story as told so far, but only to forms of life that still exist. That is true, and it is an admission that has to be made. Fossilization in its most usual form is the gradual substitution of mineral substances for the hard parts of an animal's body: until an animal has hard parts—either an internal skeleton or an outer armour—until in fact it has something to fossilize there is little in the way of evidence that it can leave behind. The biologist therefore has to fall back for guidance on what is only a secondary aid for later periods, the comparative anatomy of living forms. That may seem a questionable method. But before anyone condemns it let him realize how, quite obviously, evolution does and does not work. It does *not* work on a straight line of progress towards ever higher forms, killing off the outworn experiment before proceeding on the next. If that were so the coelocanth or hollow-spined fish (to take a popularized example) would not be found today in the same form as its fossilized forbear of millions of years ago; there would not be corals, there would not be shrimps, or ants, or turtles—the list could be extended indefinitely both forwards and backwards in time.

Evolution, rather, works to create forms of life that fit, that as we might say come successfully to terms with, their environment—that environment including the other forms of life with which it lives. Then, so long as the environment does not change too drastically and the fit is not too meticulous, that particular life will continue to flourish. Comparison between present and past life is accordingly not barred. Only it must be made intelligently and carefully and honestly: the process may be criticized in detail but not in principle. We shall most certainly never discover a fossilized amoeba; but it is a reasonable supposition that the first one-celled animals were much like this simple and protean creature that is still with us.

Nor for that matter is the record of the rocks completely blank concerning animals that lacked that inestimable advantage of either an inside or outside skeleton. The very lack of them in the early deposits of these sedimentary rocks is an indication that such forms of life did not yet exist. Then even the soft-bodied animals can leave trace of their existence, their shape, their mould, just as the ripples of the sea on the sand and the footmarks of ancient beasts have at times, by some sudden cataclysm, been preserved. Before the skeletoned animals there have been preserved the silicate spicules of certain sponges, the burrows or tracks of worms and—so far just one example which nevertheless justified its citing as an example a few paragraphs back—the mould of a jelly-fish. To go even farther back in time, the very presence of certain minerals in the rocks is an indication of life at the time they were laid down. There are in places layers of carbon, great layers of iron, the presence of which can best be explained on the basis that they represent the residue of organic life. Limestone beds of the ocean, whether they are now covered by the waters or not, and certain great stretches of ooze, are nothing but the residue of millions upon millions of single-celled creatures that had learnt to grow a shell or skeleton like their much bigger companions of the sea.

One more thing the geologists have taught us, with lately the chemist and the atomic physicist to help them or correct, and that is the distances in time, the tremendous distances in time, since the various forms of life came upon this earth.

And here, if the story is to be readily intelligible, something has to be learnt—or if not learnt at least set down, studied a little, and constantly referred to. That is a chart of the divisions of time—the Eras and Periods—into which the geologists have divided the earth's history. They have not divided it very systematically, or at least their nomenclature is not systematic, for they were a romantically minded rather than a disciplined people. For this reason the chart here given needs some explanation.

Eras	*Periods*		*Approximate Dates of Beginning, in Millions of Years*
Quaternary	Recent or Holocene		1/50th
	Pleistocene		1
Cainozoic (or Tertiary)	Pliocene		15
	Miocene		35
	Oligocene		50
	Eocene		70
Mesozoic (or Secondary)	Cretaceous		120
	Jurassic		150
	Triassic		190
Paleozoic (or Primary) (or Pre-Cambrian)	Permian		220
	Carboniferous	Pennsylvanian Mississippian	280
	Devonian or Old Red Sandstone		320
	Silurian		350
	Ordovician		400
	Cambrian		500
Proterozoic			1200
Archaeozoic			2000
Azoic			?

The first curious thing is that although the Paleozoic Era is also called the Primary there are shown three earlier eras. The reason is simply this, that the Paleozoic marks the beginning of fossils, at least of fossils in any abundance, and perhaps rather naturally this seemed to the pioneer geologists the real beginning. Nowadays, although earlier eras have to be recognized, the three original terms, Primary, Secondary and Tertiary have become too well known to be discarded without creating worse confusion.

Now for the meaning and significance of the names. Zoic—and here the classical scholar must be patient, if we stress the obvious—comes from the Greek zōos, living, and zōon, an animal. Azoic means no life; archaeozoic means primeval life, proterozoic means former or prior life. This sounds rather as if the latecomers were hard put to it to find suitable names. The three are sometimes lumped together under the title of Eozoic or Dawn of Life, which is perhaps more expressive. The three original divisions have more reasonable and easily remembered names: Paleozoic, Ancient Life (the old 'Primary'); Mesozoic, Middle Life (Secondary); and Cenozoic or Cainozoic, New Life (Tertiary).

These three great Eras are divided into Periods, and here for a time the discipline of Greek is abandoned for the freedom, not to say chaos, of romance: the names for the divisions of the Primary and Secondary Eras were given largely as their governing rock formations were discovered and segregated, and they most often reflect the geographical place of their first discovery. They are as follows:

Cambrian: found in Cambria or Wales.
Ordovician: after an ancient Welsh border tribe.
Silurian: ditto.
Devonian: found in Devonshire.
Carboniferous: coal bearing.

[Here the American palaeontologists stake a late claim and, rightly proud of their own contribution and their own country's richness in fossils and at the same time desperately trying to restore consistency, divide the Carboniferous period into two other place names, Mississippian and Pennsylvanian.]

Triassic: after a *three*-fold formation found typically in Germany.
Jurassic: first found in the Jura mountains.
Cretaceous: meaning *chalky*.

With the Tertiary or Cenozoic Period we return to Greek with a rather hair-splitting set of qualifications of this word *kainos*, new:

Eocene: dawn of new.
Oligocene: slightly new.
Miocene: less new.
Pliocene: more new.
Pleistocene: most new.
Holocene: wholly new.

Sometimes the last two are split off into an entirely new Era and lumped together as the Quaternary—it is the era of the rise of man.

As a final point: the Periods are sometimes divided into Lower, Middle and Upper; all that needs to be remembered here is that we are speaking in terms of layers of rocks and that the 'lower' is therefore the older.

That is a long digression. But it had to be made; for whether or not those divisions are referred to in this book they will certainly be met repeatedly by anyone reading about the earth's crust or the life that has been found on it, and—to put it negatively—the infallible way to become muddled and irritated is not to be clear at the start.

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Now we can return to our story of evolution, which was left with the worms that were not flat. To bring them into the time picture, the eight hundred million years or so of the Archeozoic Period—that quite unimaginable span, at some time in which life must have as it were with infinite pains gathered itself up into the self-perpetuating cell—that Period has passed and the Proterozoic, almost as long, is now drawing near to its end. Life, as we said, is going to achieve size and bulk, purposive bulk and not merely the hollow amorphousness of the sponge or jelly-fish. And to take that step a new invention is needed.

That, to make no more mystery about it, is the invention of blood.

Blood is the great transport system, the great carrier around the body of fuel and oxygen. The flat-worm can do without blood simply because it is small and flat : down the centre is a digesting cavity, all around the body is the oxygen of the water. But with the segmented worms that now come into the picture the section of the body is round and the roundness is possible just because these creatures possess this remarkable fluid that is pumped through fine tubes to all the essential parts of the body.

'The blood,' says the Bible, 'that is the life thereof.' In all but the most primitive forms of life blood is an essential. It may not be red ; in some forms it will do less than in others, insect blood for instance not being a carrier of oxygen ; but much will be added to its duties by the time it has reached the efficiency of our own bodies. Its appearance in life's history is a great event.

Surprisingly enough these lowly creatures the worms show yet two more advances. One is to possess an organ the lack of which seems to us hardly credible : it is what the Bible calls descriptively the purge and the scientist, using Latin, the anus. The coelenterates, the hollow-bodied, and even the flat-worms, have a digestive system so simple that the unwanted products, like the disappointed Omar, came out by the same door as they went in.

The other advance has much evolutionary importance, as we shall see shortly. This is the property of the *annelid* worms, which word means ringed but would have more significance if we translated it as 'segmented'. Here for almost the last time we shall have to take a living animal to illustrate our story, making the assumption that something very like it, its probably more embryonic, less specialized forbear, existed in the later Proterozoic seas. The earthworm is an annelid; but most definitely no life had yet emerged from the waters and for our example we take a worm of the sea coasts, the *Nereis*.

This is another animal that has been given a Greek name not severely descriptive but romantic, for it has been named after the Nereids, the water nymphs. Whether you can see beauty in Nereis will probably depend upon whether or no you have an instinctive dislike of the sort of things that live under stones or if you have can overcome it for the benefit of purely objective aestheticism. It swims very gracefully. It is not black and flat like planaria, it is made up of a great many segments and each of these has on each side of it small flat fleshy lobes ending in a few stiff bristles. Lobes and bristles help it to swim and crawl.

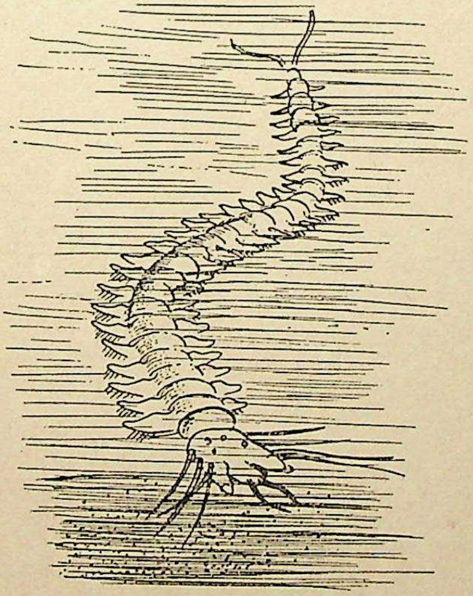

FIG. 8. Nereis

But what is significant is that each of these segments is, until the head is reached, virtually identical, with its own blood vessel and nerve ganglion: the whole animal is something like a row of individuals joined together and ruled by a head.

That indeed may have been another of Nature's ways of achieving complexity, something of the opposite of the coming together of flagellates to form a colony. There actually is a marine worm that forms new individuals by creating a head every now and then along the line of segments. When it feels the urge the last member of this extraordinary Indian file metaphorically digs its toes in and breaks away. Nereis seems to have combated this head-forming tendency and retained its individuality strictly to itself. A chain of segments that does not rebel and that has one controlling head is a great advance upon a mere colony of slightly co-ordinated creatures such as a Volvox or even sponge or jelly-fish.

The segmented creature has much greater potentialities of advance. Do but turn the outer skin into a chitinous armour that will be both protection and a leverage for better muscles, do but turn those bristles of the side lobes into legs and mandibles and pincers, and there has arrived the *arthropod* or creature with the jointed limbs, that enormously successful phylum of life to which the crabs and lobsters, the scorpions and the spiders and all the insects belong.*

Those were the advances that in fact, through the long Paleozoic or Primary Era, were made—those and many others. We are coming now to the true and indeed prolific record of the rocks.

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* There is a living 'missing link' caught, as it were, in the act of doing this. It is Peripatus, a worm-like, centipede-like creature of the southern hemisphere.

CHAPTER IV

The Fishless Seas

BY the time that the Paleozoic or Primary Era begins, which is just about five hundred millions years ago, the Earth—so the geologists guess—had already undergone four of its convulsions or major revolutions, the last quite shortly before the era begins. Whatever effect this had on the existing life of the seas, there did follow after it, in the next long span of warm and comparatively equable climate, a most remarkable proliferation of animal life. It makes itself apparent in the sudden proliferation of fossils in the lowest rocks of the era, the Cambrian rocks; and it appears in this way, because, as we have said, animals had in fact something to leave behind.

That something was not an internal skeleton, it was an external covering. Armour was beginning to arrive: the tough skin, the chitinous carapace, the shell on the back. The seas while becoming more crowded with life were becoming more active, competitive and dangerous—no longer the home merely of slowly waving and pulsating, half flower-like forms.

There arrived the spiny-skinned creatures or echinoderms (from the Greek for a hedgehog), the molluscs of soft-bodied creatures, and the arthropods or creatures with the jointed limbs. The echinoderms, for the surprising reason that they appear to be connected with that most important pattern of life which is to come later on the scene, the vertebrate or backboned animal, we leave for the next chapter; the molluscs and the arthropods shall dominate this chapter as they dominated the earlier half of this long Paleozoic Era.

For the last time contemplate, then, the worm: with brain (very primitive), with blood, with reasonably organized digestion, with a fore-and-aft, and a soft body that is nevertheless segmented. Some sort of worm, it seems likely, developed into the molluscs, and another sort into the arthropods.

The molluscs inherited from the worm the soft body and the muscularity. They increased the latter; and thereby so we may imagine—for we too have a taste for their flesh—increased their attraction for enemies and so their own danger. With perhaps a somewhat changed constitution of the sea to help them, they gained the new capacity to secrete lime and to produce for themselves a shell.

At first these snails—for such they were—grew no more than a roof to their bodies. But it was a beginning, and there followed the house proper, the coiled shell that we know so well, carried on the back but large enough for the whole animal to retire into at a sign of danger. Indeed the snail is a retiring and inoffensive animal altogether, though in its vegetarian habits it has developed a remarkably efficient feeding-tool, its tongue or radula, which is a sort of living file. Then came the clam, the first of the bivalves. Here self-protection has gone to the extreme, two shells that can be fastened together over the entire body by extremely powerful muscles. The clam is not entirely unadventurous. He is a mud-burrower, and he does it in a curious way : a pushing out of the muscular 'foot', the pumping of blood into this to make it swell into a sort of blunt anchor, and then the pulling of the whole body forward after the anchor.

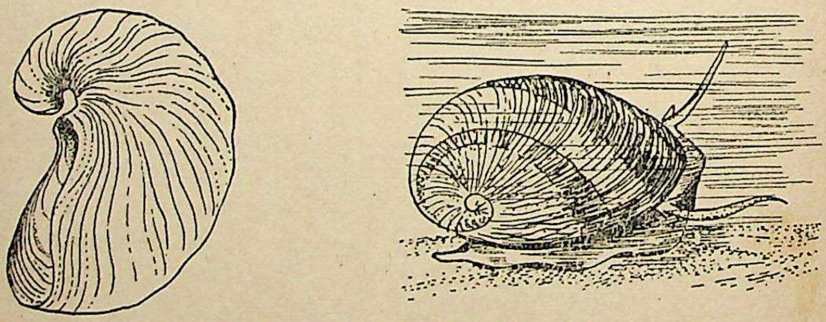

FIG. 9. Mollusc and a mollusc shell

And how is the blood pumped through a clam's body? The annelid worm manages by means of a bodily muscular process that as it were squeezes the blood along. Here something more efficient is needed ; and the answer, in one word, is *the heart*. The heart is an organ so necessary to progress in bodily efficiency that it was it seems invented by life—or evolved, or created—at least on three separate occasions, by mollusc, by arthropod, by vertebrate. Here we meet it for the first time.

We come now to molluscs that are considerably more active than snail or clam, the race's most important and spectacular representatives, both in the Paleozoic seas and today. These are the *Cephalopods*, or the 'head-footed'. It is perhaps an absurd name ; anatomically it is reasonable however, for the muscular part, which with the snail one would naturally call a foot, here grows forward to surround the mouth. It not only does that but it prolongs itself into flexible, and later suckered, arms : the cephalopods are the cuttle fish and octopuses of today and the nautiloids of four-hundred-odd million years ago. The modern cephalopods have either grown round their shelled protection or discarded it altogether, becoming thus solely armed with offensive weapons. But not so the nautiloids, who had a cumbersome shell for protection.

They did an extraordinary thing. A moment's thought will show that external armour poses one great difficulty, that of making it grow as the animal grows. The arthropods, as we shall see and as is indeed well known, do not face up to the difficulty at all. They moult; they discard their armour and start again. The nautilus, this soft-bodied creature with the muscular tentacles shooting out in front of its face, hit upon a compromise. Like the snail he builds from his body-secretions a house for himself, a simple one-roomed tenement one might say, with one side open for the face and the tentacles. Then when he grows he seals up the old home and makes a new one, slightly larger and in front of it. And so on and so on, always retaining the old. The result is a long chambered cone, with the animal sticking out from the wide end of it and carrying the rest behind. And in the Paleozoic seas these cones grew to a length of as much as *fifteen feet*.

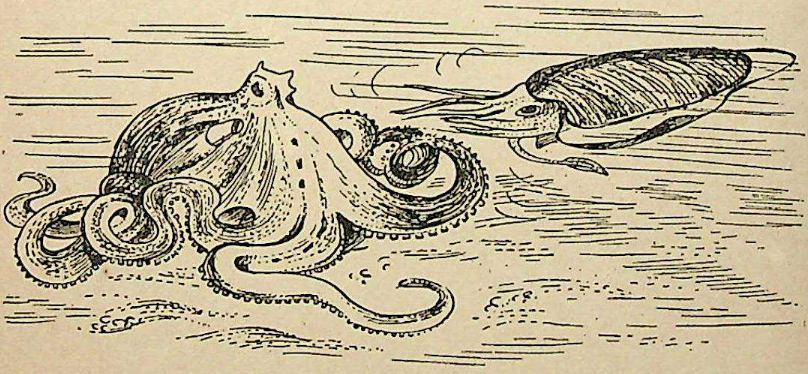

FIG. 10. The head-footed

Something more needs to be said here, for life does not act as foolishly as that, and survive. There is a survivor to this day of the nautiloids, the 'pearly nautilus' of the deep waters of the South Pacific, a minor creature that you could hold in your hand; and there are two things about him to notice, firstly that he has learnt space-saving and neatness by converting his discarded rooms from a straight cone to a spiral, and secondly that he is light because he has learnt to seal up those rooms and to fill them with gas. We may assume that the nautiloids also learnt the second trick and we know from their fossils that they in fact learnt the first: in varying degrees of completeness and neatness they too, as the millions of years rolled by, learnt to change the cone into a coil.

One more thing about the cephalopods. Their modern representatives possess extraordinarily good eyes, comparable with our own in perfection, another example of parallel evolution. Eyes that give more than mere awareness of light, that really begin to see, though it may be so far only dimly, were with the cephalopods coming into the world.

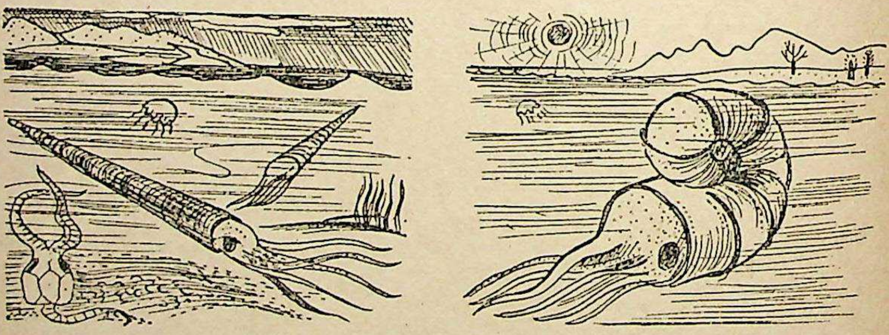

FIG. 11. Nautiloids

Finally one more thing about the molluscs as a whole. With them, *gills* arrive, essentially organs with a large amount of surface over which the oxygen-containing water will flow. As bodies grow bigger yet another process, that of respiration, can no longer be generalized but needs a special organ for the job.

Now for the arthropods of the Paleozoic seas. They in their largest manifestations were no doubt a match for the giant nautiloids. —At least they look it.

The arthropods, in short and again to speak in a teleological manner, took over the idea of *segments* and appendages from the annelid worms. They took that idea over and made a much bigger thing of it. For whereas such a worm as Nereis has only a lobe and a few stiff bristles on each side of its many segments the arthropods in their most successful forms will reduce the number of segments but will develop their appendages into jointed legs and a whole battery of tools wherewith to seize and tear and shred their food. The arthropods developed finally into the shrimps and lobsters and crayfish and crabs in the waters and on land the centipedes and millipedes, the arachnids (spiders and the like), and the insects.

That is a long list of successes. Let us look carefully at the line's archetype in the beginning of the Paleozoic Era, its most highly representative form : the *trilobite*.

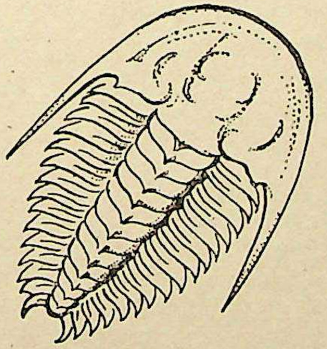

FIG. 12. Trilobite

Trilobite thrived and lorded it in those primeval seas for the incredible span of something like a hundred million years. It evolved, naturally, in that time : it changed, it specialized, being a crawling scavenger, a mud burrower, a vegetarian, a swimming predator—all of these by its varying shapes and patterns it is believed to have become. But basic form remained throughout very much the same, and that was the form of a glorified woodlouse. Indeed not so glorified, since the woodlouse is a highly developed member of the crustacean family and would probably if it could scorn its more primitive ancestor.

The trilobite started its life no doubt in the way of its kind, as a minute larva, and as it grew it moulted its hard skin and increased its segments at the rear. As an adult it had always the three divisions with which we are so familiar in the insect (though by no means so clearly separated) : head, thorax and abdomen, this last being many segments fused into one. It had also two well-marked scores longitudinally down its back, dividing it more or less into three lobes—it is this division, distinctive to itself, that gives the creature its name.

Its size ? Anything from a third of an inch to two feet. (And two feet is something: remember that the record fifteen feet of the nautiloid is mostly house not animal.) Its capabilities ? Nothing spectacular, but there were some advances. The compound eye—familiar to us in the insect—is thought now to have arrived. It gives a multiplication of not very good images ; it seems particularly able to make its owner aware of *movement*. The trilobite had the first of the paired feelers or antennae, an advance in sensitivity. For the rest the animal's all-important appendages, potentials of so much, are practically the same all the way down, glorified bristles but forked at the end to turn both outwards and inwards. The outward branch helped probably in swimming, and also rather surprisingly in respiration, the inner branch probably in crawling. There is the beginning of specialization, in that near the mouth these appendages do have a sort of toothed lobe that could have been used to hold and grind the creature's food. But here a ridiculous situation seems to arise—probably grinding motions could not have been gone through without the swimming and crawling motions at the same time. That poor mechanism is the king of the seas !

Let us be fair however. Perhaps that title may be an exaggeration, though trilobite has undoubtedly yielded easily the most common fossil of its times. Then too its later kind did probably use a trick of swimming that the lobster has developed, that of strongly flipping its curved abdomen so that it shoots backwards with remarkable speed. This has the disadvantage however that the animal cannot see where it is going : perhaps it was an avoiding action, a defensive weapon rather than an offensive. And it seems likely that towards the end of its hundred million years the trilobite did have to take avoiding action. It had now, to dispute its superiority, the suckers of the big nautiloid shooting out from the more manageable coiled shell. It had too another arthropod to contend with, the *Eurypterid* (Greek for broad winged) or Sea Scorpion.

That really was a fearsome and impressive brute. It grew to nine feet long—not shell but all animal, a great long flat body of armoured segments. It had two wide jointed flippers, like wings, with which to swim, and instead of feelers two long pincers in anticipation of the lobster. It so impressed the quarrymen of the Old Red Sandstone, so Hugh Miller the great pioneer geologist tells us, that they called its fossils 'Seraphim'. . . .

And yet as the Paleozoic Era fades away, Sea Scorpion and Trilobite and big Nautiloid, whether enemies or not, whether kings of their long age or not, all irrevocably peter out to utter extinction.

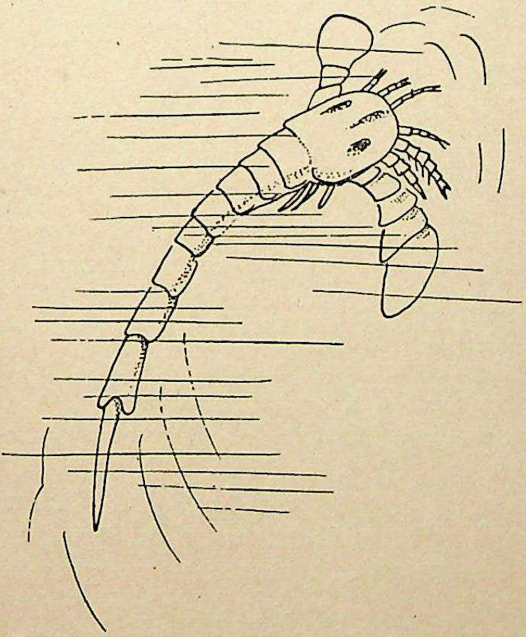

FIG. 13. Eurypterid

That is perhaps the most striking thing about these Paleozoic seas. Its most representative, successful, abundant life has died out, either largely or completely; as a rule only the lower or the less spectacular types have survived—and this applies not only to the Arthropods and Molluscs. The Paleozoic seas encompassed life as we have never known it and shall never know it, a world as far removed from the world of today as the chariot of Boadicea is removed from the motor-bus, or Daedalus from an aeroplane, or a child's painting from the sophistication of a Rubens. Yet it was the same planet that we now inhabit, made of the same elements, encrusted with the same

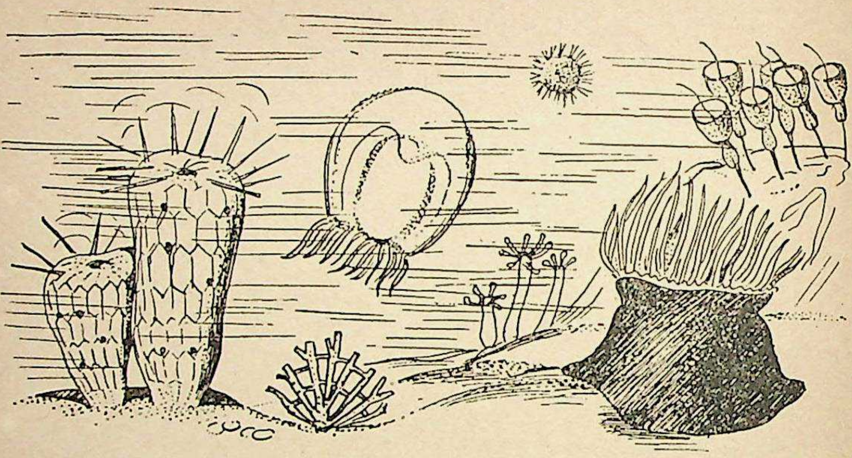

FIG. 14. The Paleozoic seas

rocks, half and more than half covered by the same waters compounded of the same immutable gases. It is a world of which our great-great-grandparents had not the slightest inkling : there is surely some significance in the fact that it once existed! Let us end the chapter by a wide glance at that ancient and self-contained world: the Paleozoic seas, lapping the barren shores, warmed by our sun, and swept by the winds and breezes of an empty and lifeless air.

The scene would naturally have changed over the immensely long period, some forms having no existence at the beginning, some rising to abundance and then sinking down again, some dying out before the Era is ended. But something of a representative picture may be given : it is of the earlier Paleozoic seas, down to the end of the third or Silurian Period of the Era.

Whether it was a scene of colour it is not possible to say; if colour in life develops in response to an appreciation of colour, or, to be more specific, to the ability to see colour by the higher forms of existing animal life, then colour would not be very apparent; if colour is something that life produces as it were out of its own exuberance, or the exuberance of its creator, then probably there was considerable colour, for many of the surviving similar forms are brilliant. That there was abundance of life and in particular amazing variety of life seems certain : life was experimenting in pattern. There were seaweeds ; there were corals. There were on the sea beds carpets of bryozoa or 'moss animals', colonies of hornily protected flower-like creatures not unlike our hydra or sea anemones, living by the age-old method of wafting laden sea currents through their hollow bodies. There were elaborate sponges and strange creatures, or rather polyp-colonies, called graptolites (Greek for scratch), that from a floating central bladder stuck out long latices of horny cup-like individuals which in fossil form look like nothing so much as the blades of a hacksaw. There were fluted brachiopods or lamp shells a little like oysters on stalks, though they are not classed as molluscs. There were five-pointed star-fish, and feather stars and—also belonging to the race of Echinoderm whose description we reserve for the next chapter—the crinoids or sea lilies, standing up from the sea bed in elaborate and curious forms that give us now perhaps an impression of lamp-posts as Rackham or Walt Disney at their most fantastic might create.

And through, and over and around this slowly waving multiplicity of life, often beautiful in form, swam and crawled and burrowed the snails, the clams, the tentacled nautiloids, the feelered and many legged and armoured and ubiquitous trilobites and the terrible sea scorpions.

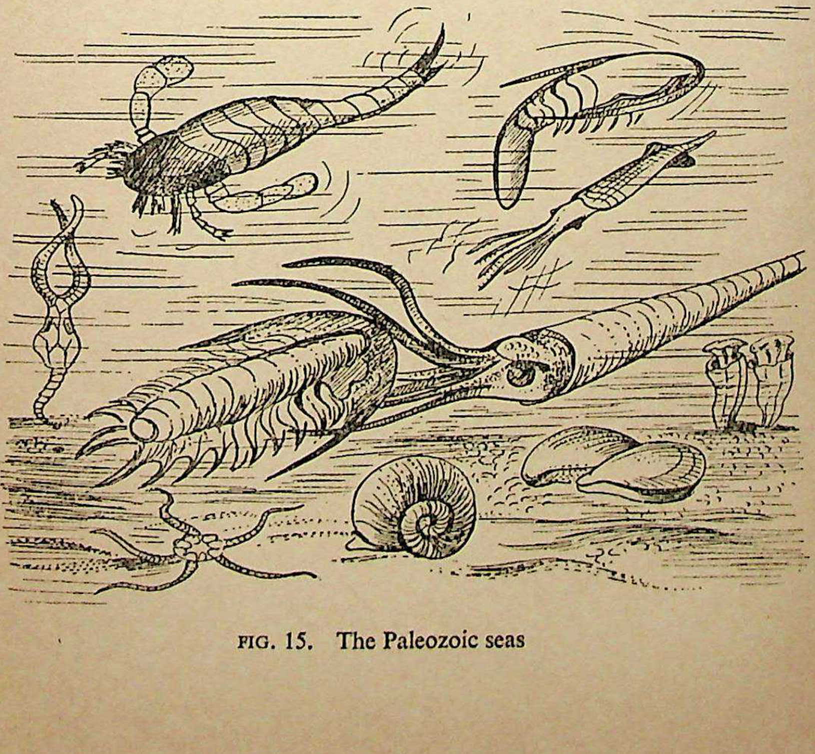

FIG. 15. The Paleozoic seas

Life had little sensitivity and very little brain. It was not skilful, it was not speedy. Its varied representatives lived off each other, no doubt in an ordered cycle or hierarchy that only changed in detail or by chance. Creatures, one imagines, ate, without emotion and without pity, what came their way—what they oozed over, crawled over, swam against or wafted into their impersonal mouths.

CHAPTER V

Streamline

AQUARIA of tropical fish are a common sight these days. The little trickle of oxygenating air goes up; the tiny rocks and grottoes and water weeds stand stationary and a trifle distorted by the water, and the little fishes dart. Watch the little fishes! The slightest flick of their tails and supple bodies and they have shot forward, changed their direction or turned instantaneously in their own length. They are complete masters of their element. They are *quick*.

That undoubtedly is the next great step in the story of life, quickness of movement and quickness of reaction—the two are likely to develop together. Until the first true vertebrates, the fish, arrive in the waters there does not seem to have been any really efficient swimmer.

But though its rise is not easy to follow in the record of the rocks, this expert swimmer with the quick reactions is not likely to have suddenly appeared. It represents an entirely new pattern of life, the pattern that has a strong but supple central axis on which to support its symmetrical limbs and muscles—in other words the backboned animal or *vertebrate*. The backbone however is preceded in time by something much less efficient and strong, and the appearance of this we must trace. It brings us back first of all, as we said it would, to a quite different pattern of life that grew up with the primitive molluscs and arthropods but which unlike those two never achieved a form that gained to life on the dry land. This is the echinoderm.

Most familiar of the echinoderms or spiny-skinned animals are the star-fish, so beloved of the artist and the old-fashioned photographer as symbolic of the seaside. It is not quite so ubiquitous as these gentlemen seem to believe, and its relations, the feather star, the prickly-ball sea urchin and the sea lily, are even less often seen. The sea lilies are direct descendants of those prolific 'crinoids' (merely Greek for lily-like) of the Paleozoic seas and represent as it were a relation of the star-fish that has decided to grow a stalk and to relapse into the sessile habit of so much of early life.

The great achievement of the echinoderms was what is called a water-vascular system, the ability to pump water in and out of an array of tiny 'tube feet' by which it can move and cling. The star-fish can cling so effectively that it can even open the shell of a clam, a tug-of-war which the star-fish apparently always wins, the prize being the loser as a meal for the winner.

But it is another characteristic of the echinoderms that gives them their significance in the evolutionary story. They possess the habit which is so surprising to us but which so much of invertebrate life has always possessed, of living in two forms and phases, a larva form and an adult form. As is usual, the two are very different.

They are so different that whereas the adult plan is radiative from a centre the larva has a *bilateral symmetry*.

That phrase 'bilateral symmetry' must make the self-conscious vertebrate take notice. It is a fact that the echinoderm larva is hardly distinguishable from the larva of one of the *chordates*, and the chordates are the group of animals who possess that less efficient precursor of the backbone of which we recently spoke. In other words the echinoderms on the one hand, and on the other the chordates who are the fathers of the vertebrates, must have had a common ancestor, some wormlike creature perhaps, a proportion of whose descendants took what seems to us the straighter course that has led to man, and a proportion the strangely aberrant or at least less obvious course that led to the spiney-skinned, half-sedentary form of life that has never emancipated itself from the sea. This likelihood is strengthened incidentally, so the bio-chemists now tell us, by some similarity of the blood in the two phyla.

The chordate has a *notochord* or chord-up-its-back. This, made of a very particular kind of tissue holding water under pressure, is both stiff and elastic, and it forms a splendid anchorage for muscles. Further, above this there runs for the length of the animal a central nerve chord. Later the vertebrate is going to change that chord of cartilege into bone whilst yet retaining much of its flexibility and it is going to protect the nerve chord by providing a hollow tunnel for it actually within the backbone. That is the way of it; and it is a tremendous advance.

The little animal that best illustrates the advance is a primitive sand-burrower and cilliate-feeder, *amphioxus* or 'sharp-at-both-ends': its English name is descriptive in much the same way and is *lancelet*. Lancelet is almost transparent, and its transparency shows how muscular it is.

Another chordate has taken the primrose path to sedentariness and has become the sea squirt, a double-opened sack-like creature that has the sole offensive weapon of squirting out water when disturbed. But its larva has a notochord. A third kind, and the most primitive, is the one whose larva is so like the echinoderm's. This is the acorn worm, another sand-burrower and swallower. The 'acorn' is an extensible proboscis that digs a way for the mouth, and this part of the animal is, again, very muscular.

Of these three only the remains of something that must have been very like the lancelet are found in the record of the rocks. It is escape from the bacteria of decay by such accidents as being quickly covered with mud or silt that causes an animal to be fossilized, coupled of course with the possession of hard or bony parts; and these precursors of the fish do not greatly qualify on either count.

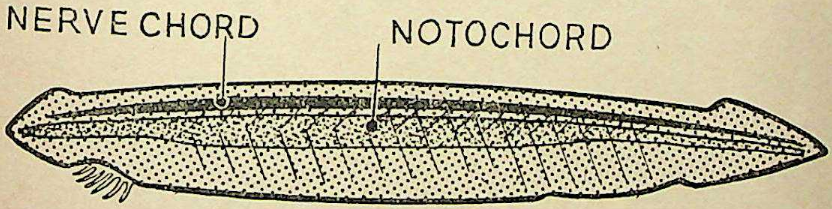

FIG. 16. Amphioxus

One particular reason for this, it is believed, is that fish most probably evolved not in the seas but in the rivers, where the need to contend with the current would foster the development of both muscle and swimming powers.

The first true fish to appear in the record are jawless and armoured. They are in their reconstruction queer and rather horrible things to see, with a round sucking O for a mouth. In this respect only there are fish like them now, the lampreys and hag fish; these have taken the perhaps easiest course for the owner of such a mouth: they prey on other fish, boring into them and eviscerating them.

Later, jaws were formed. Stronger and better armour was formed too; indeed the fishes, like so many forms of life, burst forth, once they have got a hold upon their environment and established themselves, into a kind of frenzy of fantastic variations. Some, with their heavy armour and single pair of plated wing-shaped fins, are more like some new sort of arthropod; another has a rounded armoured head that seems to bring one back to the trilobite. With the invention of the hinged jaw there returns to the seas the sort of giant terrorism of the nine-foot eurypterid or sea scorpion. One kind, called rightly Dinichthys, or Terrible Fish, achieved double that length.

But these and others were aberrations, life's unsuccessful experiments of which there must have been, through all the story, very many more than we have ever traced. These armoured fish were boned outside and not in, for their spinal chord—that all-important girder upon which the vertebrate hangs his limbs and his muscles and his success—was, though better than a notochord, as yet only

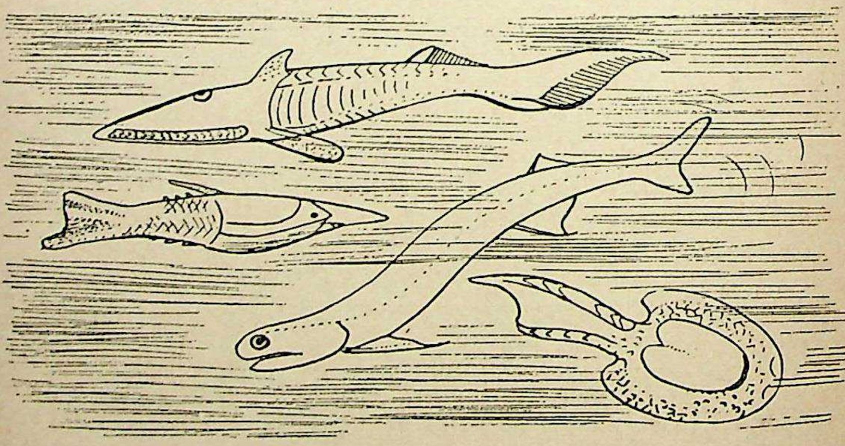

FIG. 17. Some early fish

gristle. (Some fish, the sharks and dog fish, have remained in that state to this day.)

Armour plate with a hole for a mouth gave way to a skull, a *brain-case* that is to say, and a properly hinged jaw. What had been something like chain mail gave place to glistening and flexible scales. And in some fish, on the whole the more active fish, internal gristle turned to bone, in fact to a whole spreading system of bones that strengthened the compact animal as iron mesh strengthens ferro-concrete, while yet retaining great flexibility.

The fish really was for life a tremendous advance in efficiency. This business of muscle and speed and the vertebrate form must be considered again more closely. It is not with its fins that a modern fish swims, but with its tail and the whole of its body. It is compact and streamlined and muscular around the flexible fulcrum of its backbone; by contrast all forms of life that came before it are groping and clumsy.

Room for the brain is there too, protected by the hollow skull. When the nerve-net of the coelenterate changed to the nerve system of the worm we began to speak of brain. But that is something of a courtesy title; ganglion might be a better term. Now brain proper does appear: something that can receive messages from the senses, that can co-ordinate them and consider them and can send messages flashing back to the muscles down the straight central path of the nerve chord protected in its tunnel within the backbone.

It is interesting to see what are the senses of the fish, that is to say the modern fish; how efficient by human standards could life become in the sea. We must be careful not to confuse ourselves however. Fish took some three hundred million years to produce the kinds with which we are familiar now—salmon, herring, conger and so forth, and these are found in the record only some fifty million years ago when the modern sort of mammal was beginning to develop; yet life was beginning to climb out of the sea before even some kinds of fish had lost their armour. Nevertheless the *potentialities* of more efficient response to environment were there in the fish-pattern of life; if those potentialities had not existed the vertebrates could never have developed on land as they did while their relatives in the water were developing on fundamentally parallel lines.

Fish cannot see well at a distance, their natural focus is a few feet, as opposed to ours at what the camera calls infinity. The reason for that is fairly obvious: water is seldom a clear medium for any distance. In the same way smell cannot be wafted from a distance on the breeze. Fish can smell, but only at a short distance—we for that matter could not smell at all if our nostrils were not damp. Dampness is also needed for taste, and there fish have an advantage over us, if it is one. The cat-fish is said to be able to taste all over its skin; it seems certain that it can taste with its feelers that trail beneath it—rather as if we sought our food with a trailing tongue.

Fish must hear most inadequately. Again water is not a good medium, and their ears are primitive and wholly internal; perhaps they feel vibrations rather than hear them. Indeed it is believed that the vertebrate's ear develops from the front end of quite a different sense organ, the 'lateral line', shown by special pores in the skin, that all fish possess and which the early fish presumably only possessed.

It is not easy to find out just what this sense organ does tell the fish; but it is believed that generally it makes him aware of disturbances in the water and of varying pressures—even of the barometric pressure of the air above. Fishermen know how uncannily sensitive their intended quarry are in that way. One other sensitivity the fish has, and this is something not new but likely to have been possessed by all sea life before it: a reaction to the chemical contents of the water. This is not a localized sense organ but a general one giving a reaction—as I think we can well imagine—of something like pain. We perhaps have the residue of it where our skin remains damp, the smarting of nose and eyeballs when such vapour as ammonia is in the air. To leave the sea gives life the opportunity—perhaps it is more a matter of necessity—of extending the *range* and accuracy of its sight and smell and hearing; but there are other sensitivities that will be lost.

One other possession the fish evolved that has nothing to do with brain and nerve and sensitivity. It has to do, initially, with respiration, and it has great significance in the spreading out of the vertebrate pattern of life over the dry land. This is the fish's air bladder.

Vertebrates run to *size*; they excel easily all other forms of life in this respect. Before they appear in the sea, except for the giant scorpions, for the exceptionally large trilobite, for the nautiloid bulking out his size by trailing his discarded homes after him, life is at the most measured in mere inches. But with the fishes both usual size and out-size increase. And, as we have made plain before, to achieve bulk there must not only be good blood circulation but good oxygenization of that blood. The best tool for this in the water is the gill, a large surface, close under which the animal's blood is pumped and over which the element in which the creature lives is forced; and with their swift motion through the water the fish have the opportunity to develop very efficient gills indeed.

That normally would be sufficient. But for reasons which will be explained in the next chapter, fish were often having to live in water that was growing increasingly stagnant. Oxygen dissolved in the water was becoming more and more difficult to extract. Some fishes therefore developed virtually a double method of respiration: passing water over their gills but also growing an embryo lung in the shape of an air bladder, richly supplied with blood vessels, and gulping air into this.

The curious thing is—an example of the occasional parsimony of Nature as opposed to its usual profligacy—that in most modern fishes this extra breathing apparatus has been developed into something quite different, a bladder used as a ballast to help the animal to swim in different depths and as an additional form of pressure-gauging. Often it does not connect with the outside air at all.

There remain however to this day the lung fish; and they no doubt are the descendants, the less adventurous descendants, of the fish who eventually learned to live on dry land.

CHAPTER VI

The Terrors of the Land

HOW dangerous must have seemed existence out of the water; how difficult for life, that as yet through all the millions of years had known no other home, to struggle out of the water's all-embracing protection! But on the other hand what opportunities it gave! There was the fact too that the seas had ceased to be the safe place they once had been: the life to which it had given birth had come to feed upon itself—and not much of it was vegetable or even vegetarian.

The senses of the fishes, as we have seen, are by our terrestrial standards dim senses; their world and the world of those that live with them is a dim world of near silence and of shapes passing as shadows. To progress, with senses of such quality, into the extremes of a land environment was obviously going to be a most tremendous and adventurous step.

The sun would be there to burn, the winds to buffet, the snow and ice to freeze the new life; the sudden darkness to terrify it and the drought to desiccate. Then how agile and confident life is becoming in its wonted element—and how clumsy is all sea life, even as we know it today, once it has climbed out of the waters that lave it and support it and take its weight. Nor will food be wafted easily into the waiting mouth, nor ever-present dampness make the absorption of oxygen a mere simple habit. With some or all of these difficulties life —life both animal and vegetable—had to contend.

It is a natural question to ask: why did the great invasion ever take place? We cannot say that Life felt the urge for we have no grounds for giving life a personality in that way. It may be that the Creator felt the urge; but of that we cannot judge. We can say legitimately however that life does seem to seize the opportunities that are offered.

Quite obviously animal life could not and would not spread over the primeval bare rocks. Those rocks had first to be clothed with green: vegetable life had to lead the way. It did so as there is evidence in the fossil records to show. A third of the way through the Primary or Paleozoic Age, when the Silurian Era of the sea scorpions and more elaborate trilobites was giving way to the Devonian Era of fishes, the change began to be made and the invasion to gather way.

We have said very little about vegetable life in these chapters. But so far there is very little to tell. The sea is by no means bare of vegetable life; but at all times it seems to have been largely unicellular, vast populations of green flagellates or else those more complicated and often very beautiful microscopic forms called diatoms—part of what is called plankton (Greek for 'wandering', that is to say drifting with currents) or, more dramatically, 'the pastures of the sea'. For the rest, there grew up, following that first useful habit of colonization of single-celled forms, the seaweeds, plants that learnt to attach themselves to the rocks or the sea bed (but not to grow roots) and to float out into enormously long streamers, some buoyed up by the serried pimples of miniature gas bladders with which we are so familiar at the seaside.

Now the reason for the gas bladders is perhaps fairly obvious but also significant. It has to do with our old friend chlorophyll and the miracle it performs of photosynthesis or making-something-out-of-light. Light soon disappears as you sink down into the depths of the sea: vegetable life therefore can only exist near to the surface.

The intertidal reaches must in fact have always been the favourite place for the seaweeds. Indeed, just so far as the benefit of sunlight was concerned the plant would be better served if the sea retreated and never came back. And that—though naturally not in a day—is what happened: the level of the seas sank, and along their marches did not return. The reason was that the Earth was due for one of its great climatic revolutions.

In late Silurian times, something like 330 million years ago, the earth's crust buckled, great mountain ranges were thrust up, great deeps created, and many of the shallow seas drained into those deeps, leaving behind thick salt deposits and rich overlays of organic marine sediments. Something of all this had happened before, but no two Revolutions are likely to have been the same nor were the seas the same seas. Now apparently the seaweeds were strong enough to take the next great step. The opportunity now presented was taken.

The adaptation of plant life to the land does not impress us as being so great a step as does the similar effort of animal life. But it was big enough. Put shortly, the plant had to do these things:

Produce a better internal transport system;

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Prevent itself from drying up;
Provide a means of standing up;
Propagate in a new way.

The transport needed is of food and water: the water, with its mineral salts, will need to be drawn up from the ground and taken to the food factories, the green leaves, which must obviously be near to the light. That this may be achieved, cells actually die for the plant's sake and form the walls of hollow tubes up which the sap rises—forming, as every schoolboy knows, the 'transpiration system'. The food distributing system is much more like an animal's: the cells remain alive and their protoplasm actively passes the food along. Rather more obvious are the methods by which plants prevent themselves from either drying up or falling down: the roots by one of the economies of nature became anchors as well as syphons; cells again died and formed an even stronger outside stiffness—wood, or woodiness, or varnished stem.

As for propagation, that is a very long and complicated story—which we will not try to follow in detail. It was achieved one might say firstly by an unintelligent, it appears almost as a despairing, wastefulness and then by the creation for each single act of propagation of 'a private sea'.

For, once again we must appreciate, the sea had made things so much more simple and easy: the showering of male and female elements into the surrounding waters to float or swim to a union. The first plants and trees met the difficulty in a way that was not only wasteful but complicated. They produced millions upon millions of 'spores', sexless reproducing cells that carried their own small store of nitrogenous food. These floated down to the ground. The primeval forests—the same forests that have given us our coal, the forests through which flitted silently the incredible two-foot dragonfly—must have poured down continuously a haze of spores, golden as they caught the sunlight between the trees.

If the spores fell upon dry ground they were useless. But if one fell upon damp ground it might, if all else were propitious, grow into a queer little temporary plant—what is in our modern ferns called a prothallus (Greek for 'instead of a bud')—that produces beneath itself both male and female elements which unite in a strikingly animalian manner, the male element swimming to the waiting cup-like cavity of the female. Thus the early trees were in somewhat the same position as the amphibians (and in fact some insects): they were still half tied to the water. For full emancipation they had to wait for the evolution of the flowers; for the flower secretes down the end of its tunnel of invitation a spot of moisture—the 'private sea'—wherein the pollen, the equivalent of the animalian sperm, is stimulated, not to swim but to grow and find its destined partner.

That however is very many million years ahead: we shall return to the flower when we reach the insect. We are concerned now only with the green plants' conquest of the land. And that was, as we are counting time in this God-like survey, really very rapid. It was also very successful. The first plant found in the fossil record, called Rhynia, is little more than a tube that develops root-hairs within the earth, and then bends upwards into the air and light and there develops greenness and the breathing pores that are the necessity of all plants wherewith to absorb carbon dioxide in the photo-synthetic process.

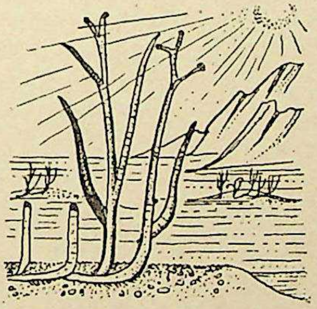

FIG. 18. Rhynia

There we can conveniently return to our story of the evolution of the animals. For the plants were really doing two separate things in their preparation of the land for the emergence of animal life: clothing the earth with vegetation, and preparing the air for animal breathing by increasing the oxygen in it and decreasing the carbon dioxide. No one is pretending that this was a conscious preparation, at least on the part of the plants. But undoubtedly it was a very necessary one.

There followed this plant life, in due course and as it were humbly, the arthropods, life-with-the-jointed limbs. Except that they had to await the plant life for oxygen and food, it may be fairly said that the arthropods had the smallest adaptations to make in order to live on land. There were the greater extremes of temperature to contend with, but at least through the long warmth of the rest of the Paleozoic Era, before the next world revolution, this was not anything to worry them very much. To prevent drying up needed no great change in their armour of outside skeleton. To adapt gills to a form of respiration using air was probably the biggest problem, and that was done in a comparatively simple way.

The first land animal to appear in the fossil records is the scorpion. And here the change of breathing apparatus is, as one might expect since he was in the vanguard, particularly simple. After all, gills are in essence only blood-suffused surfaces open to the passing of the waters; and, in order to breathe air, it is a similar surface that is required. The sea scorpion has gills something like the leaves of a book—they are called book gills—and the land scorpion has 'book' lungs. Let it be understood however that the first land scorpions had by no means reached to a true air-breathing state: they were, we must presume, half-and-halfers.

Later in the story of the rocks come millipedes, centipedes, small crawling insects something like our bristle-tails and silver-fish, spiders and—this by the time of the coal-ages when the first vertebrates were crawling about the land—insects that had conquered the air and had in the process, though obviously not of a necessity, grown to the largest size that their kind has ever achieved on this earth. Insects have no book lung nor any other sort of lung; they oxygenate themselves by an extraordinarily direct and simple method of tiny tubes or tracheæ that branch inwards from the surface into the body. It is a system that has one great disadvantage, which we will discuss when we come to the next Era, the Secondary or Mesozoic, and there survey a world where both vertebrate and arthropod are evolving and competing exuberantly. Insects and their like are a form of life utterly and perennially strange to us, with a long evolutionary story of their own, a story that stops short well before that of the vertebrate and is not in the line—thank Heavens!—that leads to ourselves. We will give it a separate chapter.

The molluscs too invaded the land, but nowhere near so successfully. They remain with us as the snail with its beautiful shell and the repulsive but no less destructive slug—both have retained that tool special to their kind, the radula or toothed tongue. Some of the snails, like a proportion of all the patterns of life that left the waters, were lured back to the easier element; always however Nature seems to point a moral lesson at the expense of those who wish to retreat: no less than with whale and turtle and salamander the land snail turned water snail has to come to the surface to breathe.

We come at length to that invasion of the land with which our own pattern of life is vitally concerned, in fact to which we owe our existence, the invasion by the vertebrates. We are ready to contemplate that significant metamorphosis: fish into amphibian.

The *amphi* or *both* of 'amphibian' is both air and water. The creature has in fact only half emancipated itself; it needs both elements in its environment. It is an animal on the vertebrate or backboned plan, that leads only its adult life out of the water, that has not yet evolved a skin resistant to drying-up; and that often prefers to wallow rather than walk. But it does possess walking limbs; it has legs.

The first amphibia of the records of the rocks are very much walking fish; their similarity to fish is apparent. Yet how and by what stages did they grow those legs? The full answer to that is, quite unequivocally, as yet unknown; unlike such well documented records as the gradual evolution of a small five-toed creature into the horse, these pages remain largely uncut. In the very stimulating opening chapters of his book *The Living Brain* Mr. W. Grey Walter, an experimental psychologist, writes: 'The amphibian emerged from the shallows and slime crawling on fins transformed over night into limbs complete with their five fingers.' He obviously means it challengingly rather than literally, but in plain fact no one can gainsay his bald statement. It is a problem to discuss at the end of this book.

But do not let us run away with the idea that the Fundamentalists win hands down or that the lack of evidence is more than one of degree. Nor for that matter must we go to another extreme: however much we may believe, some of us, that there is a purpose behind Evolution we have no right to impute purpose to individual lives. It is, rather, another example of environment issuing a challenge, of a particular form of life not necessarily wanting to change but having to change if it were to survive.

The second half of the long Paleozoic Era, the late Devonian and the Carboniferous Ages that saw the heyday of the amphibians, were not times of one of the Earth's great upheavals. But there do seem to have been—perhaps more than in the other of the long inter-revolutionary spans—very considerable rhythmic fluctuations between wetness and dryness of the climate and in the relative height of the land. Inland seas and swamps drained off or dried up. They may have come back later, for taking the long view it was a time of wetness and swamps; but no animal can wait a ten or twenty thousand years. Where had been a great lake perhaps, sparkling and fed and aerated by many streams, there would be later only stagnant water or, later still, water that disappeared entirely as spring changed to sun-baked summer.

As has been said, fish quite early in their history developed an air-gulping habit and an embryo lung to combat these unwelcome conditions—there is still, in Australia, the lung fish that survives in a nest of mud through the parched summer, waiting for the return of its proper element. But that is not a very successful method of combating the difficulty, and what if that particular lake or pool dries up for good! The only really effective answer is to use your highly muscular fins to flap, crawl, waddle into the better lake or pond. And for those who scoff at this idea the biologist will point in general to the muscularity of fins and in particular to the modern fish called the mud-hopper which does in fact move itself in just this very way and to the Devonian fossil Eusthenopteron ('strong-flippered') which looks as if it did.

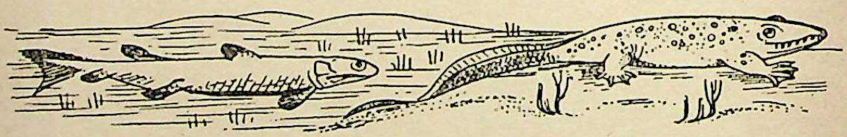

FIG. 19. The first legs?

Amphibians spent fifty millions year or more floundering amongst the swamps and the coal-measure forests and in that time they were proliferating into an amazing variety of forms. It is a variety that is not much noticed because it is overshadowed by the even greater and more fantastic variety of the reptiles that followed them; nevertheless they did have a good run for their money and assumed forms besides which the modern frogs, toads, newts and salamanders are as a housewife to a Windmill girl or, perhaps a better simile, a ploughshare to a tank. The biggest prehistoric amphibian was ten feet long, a lumbering, blunt-nosed crocodilish animal; another had the long thin jaws of a diver after fish, another had an enormously wide gape and a head like a great broad arrow; and some even had patches of armour-plating like the early fish.

But *none* of them had legs that raised their belly off the ground. Weight, the full, harsh force of gravity unmitigated by the countervailing support of water, was still too much for them; they preferred to wallow. In fact, strictly from the point of view of those that came after, it may be said that the amphibian hit upon a wonderful invention and then wasted it. Existing in their youth as a gill-breathing larvae, practically a fish; tied ever afterwards by a skin that still had to be kept damp and by their spawning habits to water; they perforce used their legs not primarily to invade the land but rather to make sure that they could always get back to water—not for adventure but as an insurance policy.

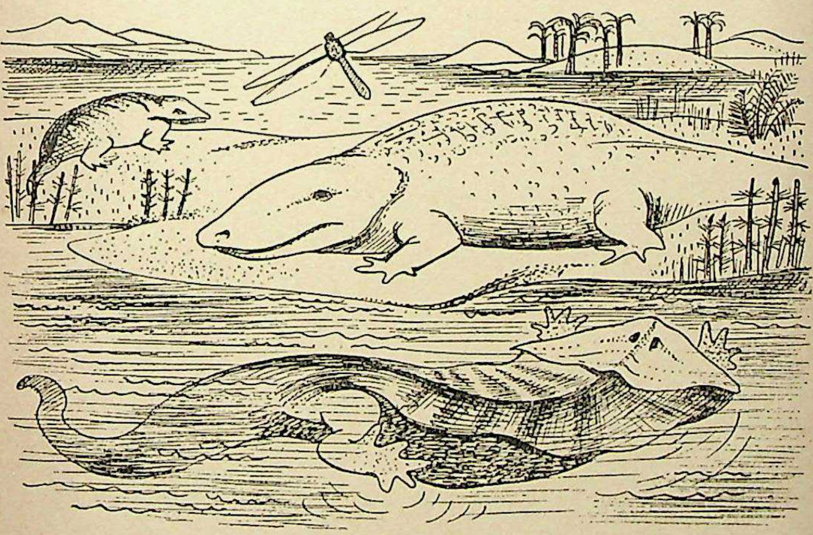

FIG. 20. Life climbs out of the water

And yet: one cannot take away from the amphibian the distinction of being the first vertebrate with legs.

It needed another of the world's great revolutions to bring forth the reptile.

This Revolution was an important one and one we know a good deal about. It comes in the Permian Era which marks the end of the Paleozoic Age. There follows what the older geologists called the Secondary Period and the moderns the Mesozoic or middle Era of life. This began some 190 million years ago and lasted some 120 millions. After the upheaval there was a time of great cold in the Southern hemisphere and of desiccation in the Northern. Steaming swamps, as the typical scene, gave place to ice or dry open plain.

The trees of the forests changed, to something more like our conifers. The insects sought ways of surviving the hard winters. Even in the sea there was drastic and ruthless change—the sea lilies and the lamp shells dwindled, the trilobites at long last disappeared for ever. And on the land there arose the opportunity for a browsing, running creature that in no way depended upon water except for an occasional drink.

The reptile in small and lowly forms had been existing side by side with the amphibian. When the world after its upheaval finally settled down to its old equable climate the big amphibians were disappearing or had disappeared and the reptile took its chance.

The reptile has a scaly or leathery skin that resists desiccation, and it *is born on land.*

There comes now upon the scene an invention of Nature that to us with our breakfast table habits may sound not in the least epoch-making but even rather comic. It is the shelled egg. No longer is the new life rocked in the cradle of the deep ; it is surrounded by its own miniature ocean, and supplied incidentally with its own store of food, and all within a protective casing.

The change goes deeper than that. The egg needs the mother's protection. It will not always get it, particularly amongst the reptiles, nor on the other hand is maternal care always lacking among the modern fish or amphibians ; but the cache of eggs is a particularly tempting meal if found unprotected and with the reptile the entrance upon the scene of mother love and maternal care is at least predictable.

There is even something further of significance. The egg is formed within the mother's body. No longer are ova and sperms cast into the water. Fertilization is internal. The female has to be found and won. Mating ; pairing ; more obvious rivalry between males—all these have arrived.

• • • • •

The reptiles that are the monarchs of the Mesozoic Era are a brainless, brutish lot, at least so they seem to us. Imprisoned in their great Gothic architecture of bone, they seem pitiable rather than heroic. All that may blind us to their considerable achievements.

First of all they raised their bellies from the ground and walked—later they ran. Secondly they came out of the slime and in the wide plains of the Triassic world basked in the full heat of the sun and suffered the full cold of the night. Thirdly they conquered not only the land but also the air and, once again, the sea. And fourthly in their exuberance they achieved a size and a variety that has never been excelled by land vertebrates and is still, however long we may gaze at their reconstructed remains, hardly credible.

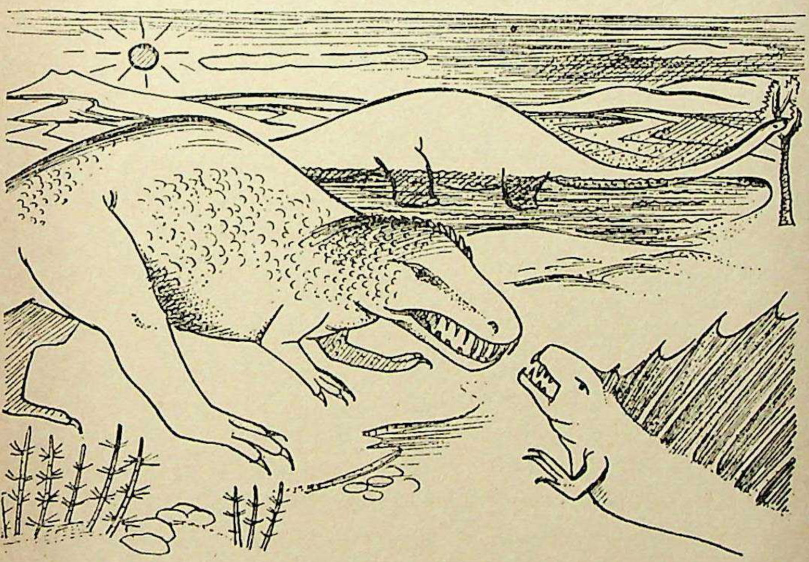

FIG. 21. Some of the giant saurians

That business of the full heat of the sun in a less hazy, swampy world is of significance. It may have been one cause of the Mesozoic reptile's exuberant variety: ultra-violet rays and queer 'sports' in life seem to be connected. Significant too is the fact that these reptiles, out in the open, were probably being subjected to greater extremes of temperature than life had ever suffered before. For there is this curious fact: the speed of nervous reactions varies with the heat of the body, slowing down as the temperature drops. The reptilian world—this land-animal world that has not yet achieved *thermostasis* or control of its bodily heat—must have been a mad and exciting and terrible world in the noonday sun, a slow and dull world in the morning and the evening, and a world of lethargy and stillness at night. Perhaps it was when cold-blooded life left the equable seas that sleep was invented.

So oft-told has been the story of these reptiles and their great size that perhaps we should even be a little disappointed if we saw them. Not all, obviously, were the record size of their species, and not all species were outsize. The earliest, Seymouria, half akin to amphibia, were only two-footers. Even Tyrannosaurus stood, probably, no higher than a giraffe. But no doubt as we gazed the awe and wonder would come back. There was no giraffe-flimsiness about the tyranosaurus; his bulk was enormous, his head a massive jaw-operating machine, and his teeth terrible. It was the vegetarians who were the biggest, and it should be remembered in their favour that it was really the reptiles who first emancipated themselves from the carnivorous habits of their fish forbears and took to plant-eating as a means of livelihood.

Perhaps more interesting than these reptiles' running-to-size is their running-to-bone. As with the paleozoic invertebrates before them, but in a greater degree, armour becomes fantastic. The ridge of plates along the back of the stegosaurus, like the ornamental roof tiles of some megalomaniac Edwardian millionaire's castle (the Greek word means roof), may have served as protection against tyrannosaurus, or against sexual rivals within his own kind. But need they have been quite so enormous, or need they have been only along the ridge of the back—was not even the tiny brain of his adversaries capable of the stratagem of bowling him over on his side? One of the earlier saurians, Dimetradon, grew even taller spines along his back, which, connected by a webbing of flesh, give the appearance of a sail or one of those thin modern central-heating radiators. That, in fact, if it was suffused with blood vessels, was probably its use: stand in the rays of the sun, and you were saved from what must have been the reptile's terror, a freezing of the veins; stand in the wind and the shade, and with remarkable speed you cooled down.

The flying pteronadon had the most fantastic elongated spike to the back of his head, as if he carried about his own hat-stand. Perhaps that helped to balance his equally enormous beak. But perhaps it did nothing of the sort, perhaps it was merely Nature in one of her moods of not knowing when a thing has gone too far. To explain some of these exuberances and exaggerations in terms of survival value taxes the ingenuity of the most enthusiastic biologist.

Nor must we make too much of these beasts' brainlessness, though in all conscience it is striking enough. Brain, obviously, does not have to be strictly proportionate to size of body. Nor has brain developed anywhere yet to startling efficiency—the modern swift-darting fish, the intelligent octopus, the elaborately co-ordinated lobster, have not yet arrived.

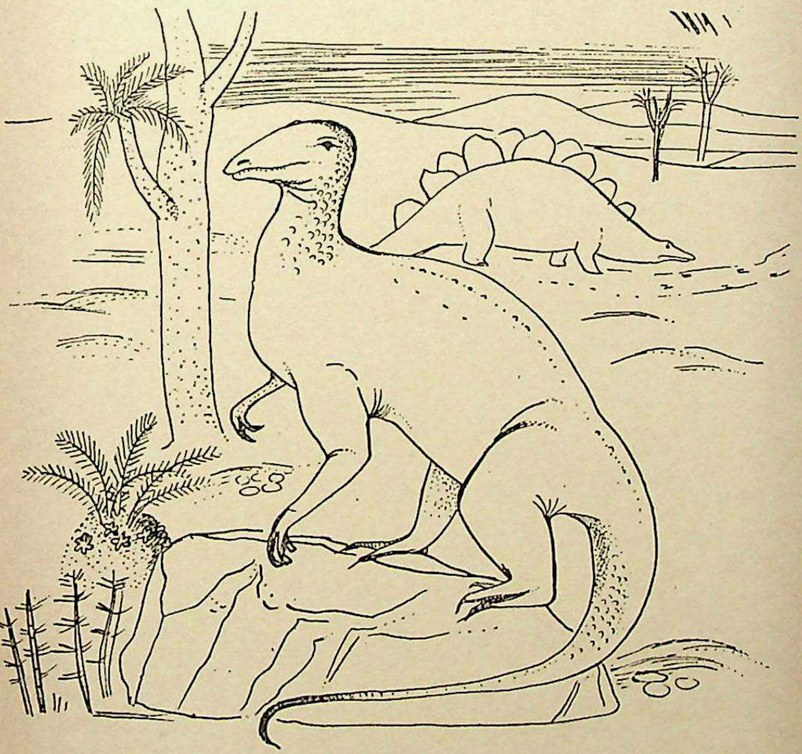

FIG. 22. More saurians—stegosaurus in the background

It is the clumsiness of the big saurians that is more significant. With their colossal weight and size perhaps much brain would not have been of great use to them: it would have been like fitting a steam-roller with the controls of a jet-fighter. It is significant that these giants often had a bigger nerve-ganglion somewhere about the region of their hips than the brain in their head : the slow messages had less far to travel.

Nevertheless, and finally, do not let us make any bones about it : they were a brainless lot. If ever the world has been ruled by brute force and ignorance it was through the hundred-odd million years of the Mesozoic Era—the land that to their fish-like ancestors must have seemed terrible in its harsh emptiness they had now made more terrible by their presence. With the great advance of the new life being born within the body had come the principle of mating. And with that there seems to have come at first an increase in ferocity, rather than a birth of love.

CHAPTER VII

They Do Not Freeze

THE most usual climate of our world is such as human beings have never experienced, a warm and equable one over most of the globe.

The reptiles enjoyed a long stretch of this when the Earth had at last settled down after the major convulsion that had killed off the last of the trilobites in the sea and had reduced the amphibians from a triumphant variety to a few small and inconsiderable kinds of beast that perpetuated themselves as our frogs and toads and newts and salamanders. Then came another revolution that sent mountains bursting upwards, continents changing their shape, and cold and harshness and dryness back into much of the world. That is the last of the Revolutions, so far; it took place about seventy million years ago, it marks the end of the Mesozoic Era and the beginning of the Cainozoic or Age of Recent Life, and it killed off the giant reptiles, it would seem, as the previous one had killed off the giant amphibians. The world does not yet appear to have recovered from that last revolution, at least not sufficiently to settle down into another vast age of equability. Just about one million years ago ice ages broke out again and continued with pulsations until something so recent as some twenty thousand years ago—those last are the ice ages that have disciplined and conditioned our own race in its childhood. Whether the world will ever settle down again, whether our theory of inevitable and regular revolutions is after all not correct, or whether this time it is merely taking longer in its last shudders, we none of us, quite obviously, will ever know.

This last great Era of seventy million years, the Cainozoic or Tertiary, is sometimes also called the Age of Mammals. But it was a good deal else, and mammals were in existence a long while before the Era started. That in fact is the danger of names and generalizations. There is no neat divisioning in the history of the planet's life, the changes are not so complete and drastic as one is inclined, in a craving for neatness, to imagine. Fish had a long way to go to their present efficiency while amphibians were already flourishing; reptiles were as it were feeling their way while amphibia lorded it in their sprawling bulk. In the same way primitive mammals, while the reptiles big and small held their undisputed sway, scuttled and skulked and kept out of the way, pushed perhaps into the more difficult lands, the more mountainous lands, where the temperatures went to greater extremes.

That is at least a reasonable proposition. For life undoubtedly seems to accept the challenge of difficulties, and the mammals' great invention is a response to just that particular difficulty of extremes of temperature.

Seventy million years is still in all conscience a terrific length of time. Yet, when we have been dealing in hundreds of millions, when we were recently contemplating the first beginnings of life over a thousand million years ago, a mere seventy seems a cosy and calculable figure : from now on we shall be counting in tens and singles until we come to the last unit of all and man comes upon the scene. We are at last coming to a world like our own world, one which we can visualize and understand. Before we contemplate it it will be useful to try to have a look at the last of the Mesozoic Era, and to realize what it still lacked.

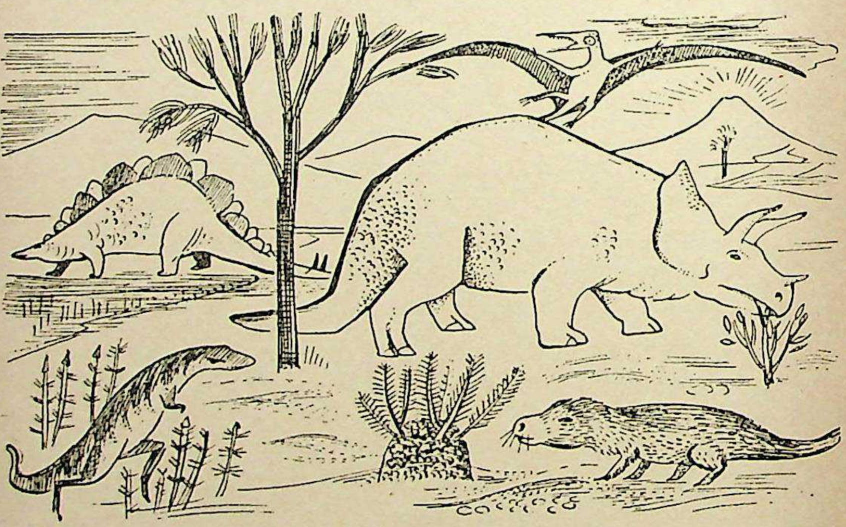

FIG. 23. Enter the near-mammals

It lacked anything changed or made or moved by the hand of Man. That is obvious. But it also lacked virtually anything changed or made or moved by life at all. Neither hand nor paw existed. Nor mind to achieve the conscious effort of making. Even the bird's-nest does not exist because there are no birds.

Herbs and grasses do not yet exist.

Flowering shrubs are only just beginning.

So too are the social insects.

Mammals exist but are not likely to be seen.

Nevertheless life is abundant. The seas and the rivers, as for so long, team with life : all that sessile, waving, flower-like life, all that cautious life hiding in its shells or under its carapaces, all that microscopic life floating or building its coralline houses, all that predacious life of fish swimming more efficiently and arthropod growing better tools and weapons out of its basic battery of legs.

The air has its insects, but hardly yet its honey seekers nor any longer the giants of two-feet wing span that existed in the coal forests.

And everywhere there reigned the reptiles, small, middle-sized and enormous. In the seas they had gone back to frighten the fishes, to grow to forty feet in length and to be only prevented from complete dominance, one would imagine, by their need to come up for breath. In the air they did not rival so much as, one would imagine, ignore the insects ; they were surely too clumsy to chase them, and too big to be bothered by them. They soared rather, these air-borne reptiles with their featherless wings, they soared over the seas, to swoop down and catch fish—yet another enemy for the unhappy founders of the vertebrates. The pteronodons reached a wing span in feet that the coal age giant insect achieved in inches. As for the land dinosaurs they shook the ground with their stumpy pillars of legs, or scooped and wallowed and browsed in the swamps, or looking like nothing so much as giant plucked chickens they ran and darted and raided the egg clutches of their even bigger cousins. Nowadays our reptiles are the snakes and lizards, the tortoises and turtles and terrapins, the alligators and crocodiles. It is still a considerable brotherhood ; but it is as nothing compared with the variety, the ubiquity and above all the size of the reptiles in their hundred-million-year heyday of the Mesozoic Era. They suffered the most spectacular slaughter of all history.

To say that it was lack of brain that led to their downfall is surely unfair. Mammalian brains would have coped little better ; it needs a reasoning, a *picturing* brain to be able to conceive a different environment and to search for it. It is enough to say that one more invention was needed for life to succeed away from the even temperatured sea, and that was the simple ability *not to freeze.**

If the temperature drops below freezing-point life had either to creep into some hole or protected place that was not so cold, or get out into a warmer climate altogether, or die: hibernate, move, or give up the struggle. All life, out of the sea, has done that; all, that is to say, except birds and beasts, for they have found the way, so long as there is food inside them, of keeping their body at an even temperature and a temperature that is well above that crucial point when water—and most bodies are largely composed of water—becomes ice.

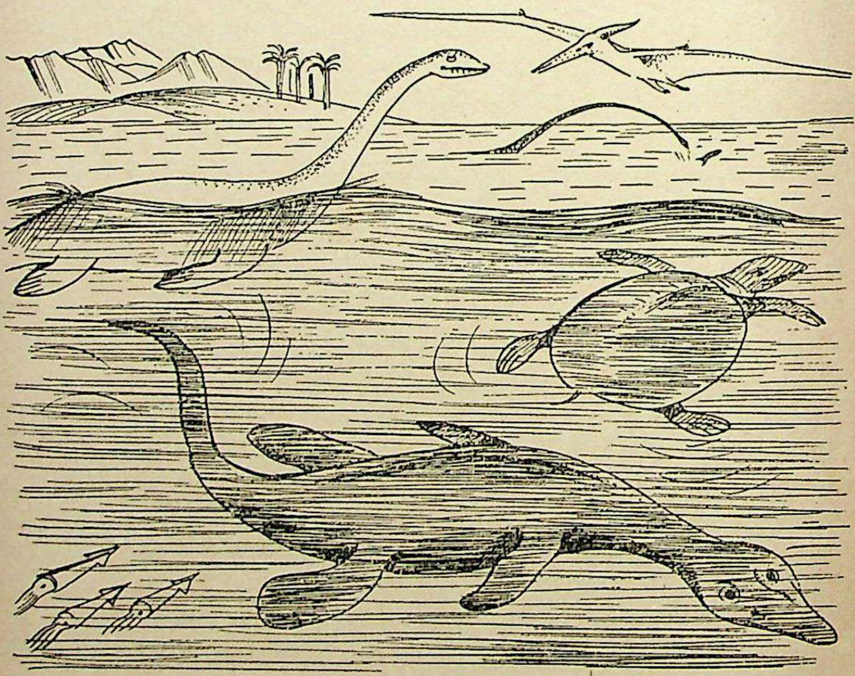

FIG. 24. Conquerors of sea and air

It is worth while to realize how this ability to stay at one temperature, *thermostasis*, is achieved.

Mammalian normal temperature varies by a few degrees between species but is round about 100° Fahrenheit. It is, one may say, a day-time sub-tropical warmth, the temperature presumably in which the Mesozoic reptiles lived and thrived. The most obvious necessity in a cooling world was to conserve such body-heat as was possessed, and to that end two great inventions were brought into being: fur and feathers. They both serve the same purpose, the purpose which our cellular underwear copies, to entrap air and so surround the body with a non-conducting jacket. Further, which is what no underwear can do, a fluffing of the feathers or a bristling out of the hairs increases the effectiveness of the air jacket. (We humans make a feeble attempt at this by involuntarily giving ourselves 'gooseflesh'.) By the movements of muscles and the activities of glands heat is generated in any animal's body ; by its covering the bird and mammal manage to keep most of it from escaping. More heat can be created by more violent exercise either voluntarily or by means of the involuntary action of shivering.

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* Why then did not the seagoing reptiles survive, at least in the warmer seas? Perhaps it needed the better brain and bodily efficiency of the mammal to survive in a foreign element.

But all that is not enough. The refinements of control, with ourselves and with most of the higher mammals, are effected through the skin. The skin acts as an adjustable radiator. A cold exterior, and the small blood vessels near the surface of the body retract. A hot body, and the blood vessels dilate, to gain what cooling is available from the atmosphere. If that is not enough, the sweat glands come into action and the cooling effects of evaporation complete the process.* All in all it is a delicate and successful series of adjustments. And it acts both ways : not only can the mammal survive the frost, it can also toil because it can sweat. A reptile's bursts of energy are never very long.

The mammal, as is well known, has two other great advantages in its mode of living. The first is a matter of eggs. That very advance which emancipated life from dependence upon water proves to have its own weakness in the more exacting element. For the female ovum has become, relatively, an enormous affair, packed out with food for the life within ; and what is food for the life within can be food for the life without—to be more specific, for the carnivorous thief. There was one tell-tale fossil discovery, of a smaller reptile with its head bashed in amongst a cache of giant reptile eggs—the thief discovered. 'It is easy to see,' says *The Science of Life*, 'that for innumerable species, the Jurassic Era was one glorious egg hunt.'

The birds have half solved the problem by flying up out of harm's way, of building the hidden nest, and of protecting the eggs within that nest. That is an advance on the reptile who, with as it were only the wasteful, casual method of water life behind it, seldom bothered to protect its eggs. But the final mammalian invention is surely the better one. The egg never appears ; it is developed within the mother's body.

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* Man shares this ability outstandingly with the horse—not incidentally with the monkey.

The other advantage is the one that gives the mammals their distinctive name: the animals who have mammae or breasts, who suckle their young. That has implications so wide and so spiritual—there is no other word for it—that we shall do better to come back to it in a later chapter.

The point to realize now is that these improvements did not appear suddenly or all together. Just as there were primitive mammals long before the giant saurians had disappeared so there were different kinds of mammals overlapping each other in time—they are in fact still doing so. There is no simple, one-line advance.

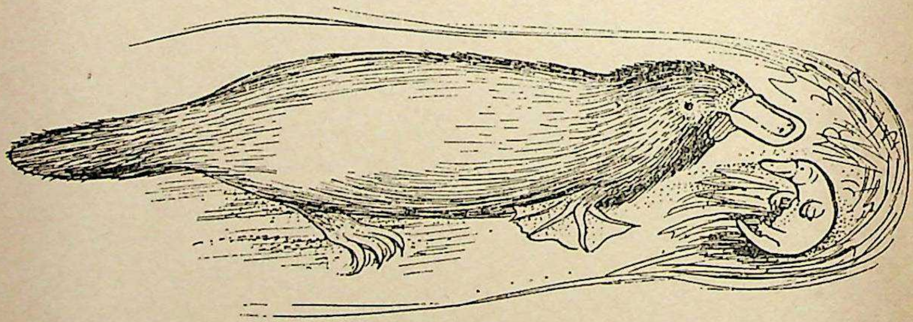

FIG. 25. Monotreme—the first milk-licker

Three kinds of mammals still exist, all warm-blooded, all giving milk to their young:

Those that have retained the habit of laying eggs and possess only rudimentary and diffused milk glands at their breasts.

Those that give birth to their young in a very immature state and proceed to carry them about in a pouch.

Those that nourish the young within the mother's body and from the mother's blood stream and produce a baby completely formed.

Of the first kind, the monotremes, there only exist now, as most people know, two survivors, the duck-billed platypus and the echidna or spiny ant-eater.

Of the second, the marsupials, the revealing thing is how amazingly embryonic is the baby when born. It is almost as if the pouch were a substitute for the eggshell. The baby kangaroo is only about an inch long. Nobody knew until a few years ago how this tiny immature creature found its way into the pouch—was it put there by the mother? The answer is that it is helped there by the mother licking a wet path in its fur, up which the infinitesimal baby instinctively manages to crawl. The baby platypus, as one would expect, is even more immature. Incredibly the eggs—usually a couple at a time—of this rabbit-sized animal are not much bigger than a thrush's.

According to the anthropologist, Elliott Smith, the Egyptians

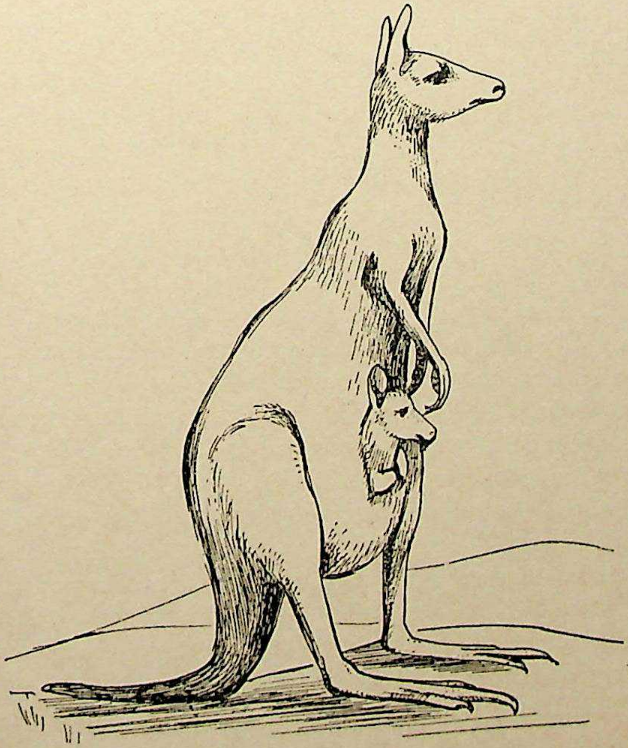

FIG. 26. Marsupial—baby grows in the pouch

saw much significance in the placenta and the umbilical cord that acts as a life-line between unborn babe and its mother. In the downright and unprudish manner of primitive peoples they used these as a symbol of life—and produced the pennant and so the flag. If that is true, then the Egyptians were a very discerning people. For it is the last great advance; it is as far removed from the careless, wasteful, as we might say irresponsible spawning of the plant and sea animal as the guided missile is an advance on a shower of arrows or —a better simile since this is a matter where love comes eventually into the picture and not mechanics or death—as the Sermon on the Mount is an advance on the danger yell of the leader of a pack of baboons.

Here we must step back and see where we are going. If Evolution is in no single straight line, why try to follow any line in telling its story? Or to be more specific, why so obviously trace the line that leads finally to Man? Is that not unconscious subjectivity, and pure complacency?

The answer is a definite 'No!' Man is obviously the highest form of life on this Earth; indeed so much so is he this that he not only successfully adapts himself to his environment but begins to control it, with the rest of life into the bargain. The deflator and debunker can add 'highest *so far*!' in a sepulchral and meaningful whisper if he likes, but that is all he is really entitled to do.

The line to be explored will consequently be the line that leads to Man. But because the end of the story is so controversial and so significant, this will be postponed. We may be able to think about that more successfully if beforehand we have explored also some of the other lines. For, as we travel through the milennia and reach at last a world that begins to be recognizably like our own, it is increasingly obvious that there are other lines—the birds and the insects in particular—that, up to a point as successful as our own, have yet produced ways of life strikingly different from our own. To contemplate what we are not is one way of helping ourselves to realize what we are.

The real truth and the right way to look at this matter is that in following the line that leads to Man we are really doing so incidentally. It is much more to the point to say that we are following—and have all the time been following—the line that has led to greater control over, and independence from, environment. Nature continually experiments, creating every form of life imaginable and indeed very many that we could never have imagined had we not seen them. Some are successful and some are not; and of those that are successful some are so in particular and some in general. The first is, specialization: the form of life that cunningly gets the very most out of a climate and a habitat. And the more that kind specializes the more difficult it will find it to survive if its environment changes. (Not, it will be observed 'when' that environment changes: the wood-louse under the stone, the jelly-fish in the tropical sea, the blind but ingenious parasite snug in the guts of its host, are, one would imagine, entirely safe so long as there is life at all.) The second way of success is the one that legitimately can be called progress, that avoids the snare of the clever and particular adaptation—the shape of the stick insect, the mud-burrowing foot and protective prison of the clam, even the horse's hoof or the hawk's large and miraculous eye (leaving little room for brain)—but, rather, acquires an increasing sensitivity and masterful reaction to whatever it may meet.

With the coming of the mammal we can watch this the most successful Class of life radiating out in time and space. As it radiates it will adapt itself. Sometimes it will meet opposition and as it were will be disciplined to a sober course, sometimes and in different places it will burst out unopposed and develop upon remarkably parallel lines; sometimes even it will burst out so madly, so exaggeratedly, that the only result can be rapid extinction; sometimes it will invade, and successfully, the elements to which it does not seem strictly to belong.

The curious thing about the evolution of the placental mammals is that it seems to have been in two main bursts, that the second edition largely replaced the first, and yet that each produced rather the same sorts of animals. The main difference was that the second achieved an all-round increase in capacity of brain.

Teeth are important in fossils for they often show a way of life. The early mammals—those coy scuttling creatures keeping out of the way of dinosaurs—were likely it seems to have been insectivores. There developed the gnawers or rodents; the burrowers; the carnivores, primitive cat-like creatures, dog-like, racoon-like. None was very big.

But increase in size seems an inevitable path in evolution. It is after all an obvious advantage. The tragedy for many species is that they did not seem to know when to stop; and since weight increases with increase in each dimension (so that a sphere of two feet radius is *not* twice as heavy as one of one foot, nor even four times, but eight times as heavy) there comes inevitably a time when muscles can hardly cope, when legs are clumsy pillars and the creature has left speed and nimbleness behind for ever. *Amblypods* some of these creatures have been well christened, the 'slow footed' creatures, perhaps bow-legged, rather like clumsy dogs or bears, that yet browsed and had heads vaguely reminiscent of a horse's. Eobasileus, coming later, is romantically, but less descriptively, named by his American discoverer, 'dawn king'—presumably of the beasts. He was the size of a tall hippo and rather like one, with however curious double knobs on each side of snout and forehead. Yet for all its primitiveness and clumsiness this creature was a true mammal; it gave live birth, it gave suck, it gave, presumably, care and mother-love to its young. It would be a great sight to have seen baby Eobasileus with its mother at play. . . .

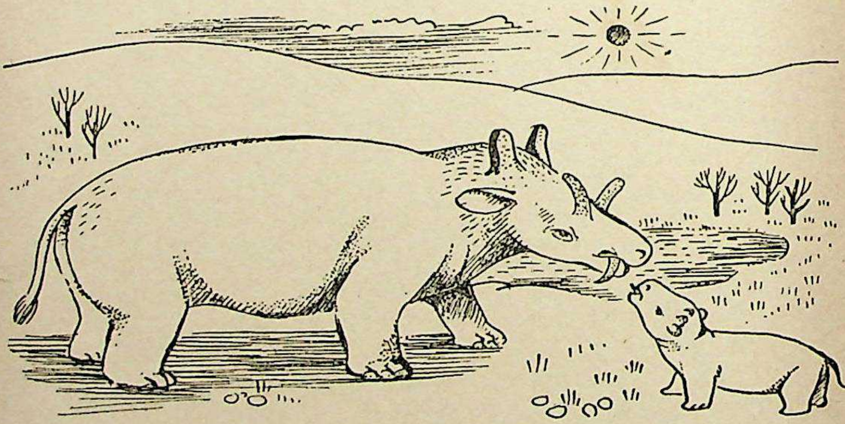

FIG. 27. Eo-eros?

With the second great wave of beasts there comes besides greater brain better and more specialized parts. There are still browsers, indeed there comes now the greatest browsers of all, Baluchithere, like some super elephant-horse-giraffe, with head five-foot long twelve-foot neck and fourteen-foot forelegs: presumably he browsed off trees.

Nevertheless the great days of the browsers are numbered. For the great days of the forests are numbered too: somewhere in the middle of the Cainozoic Era, with an increase in dryness and coldness, the grasses are going to thrive at the expense of the trees, not wholly of course, but sufficiently for great tracts to change from forest to prairie. That gave rise to the grazers, the hoofed animals or ungulates. Some of these, that we call the odd-toed ungulates, have resulted in the tapir and rhinoceros and the horse (with only one toe left) and the even-toed have given us our cattle, our deer and antelope and our hogs. Once there were hornless rhinoceroses as speedy as the small horses of their day. Once too there were giant hogs, standing six-foot high, called graphically Dinohyus or Terrible Pig. There lived at the same time Syndoceras, a ridiculous deer running to bone and, as his name implies, with two horns together half-way up its nose.

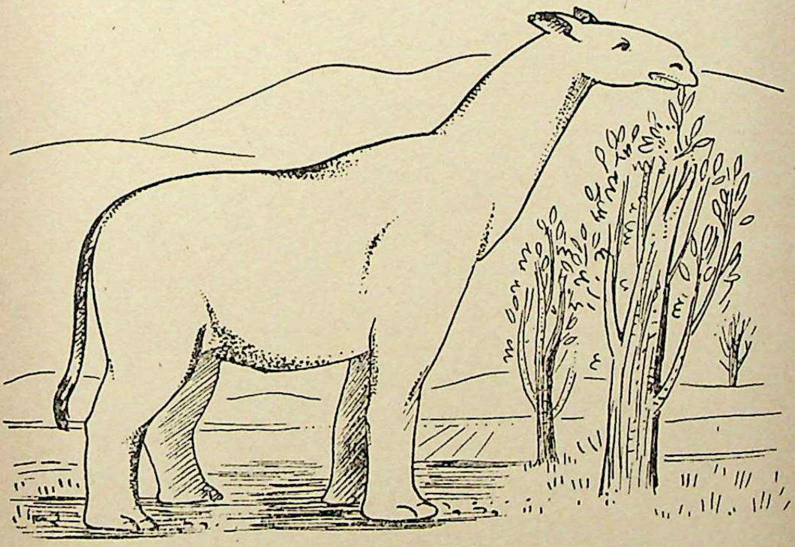

FIG. 28. **Baluchithere**

In fact the second set of mammals, though better brained than the first and giving us the mammals that we know today, was not altogether immune from that strange freakishness and exuberance of Nature that runs to largeness and extremes and that produced for extinction both the giant reptiles and the curiously parallel early giant mammals. But this second time it is as it were a *modified* madness.

As the last thirty or so million years of the Earth's history ran their course and as the land became increasingly like our own land, the mammals shed their less successful experiments and fined down to their present still wonderful but less startling variety. There were the barriers yet to pass of the Ice Ages of the last million years or so, and that would weed them out still further. And somewhere amongst them, it is known, was a small insect-eating animal, much like our modern tree shrew, that was the first primate. Its line did not specialize so much, it did not fit itself with ingenious exactitude to a very particular environment, but developed instead its senses, its *sensitivities*. It did not in fact fall to temptations of immediate gain as did some other lines: that is the idea, admittedly anthropomorphic, that we shall illustrate in the next chapter.

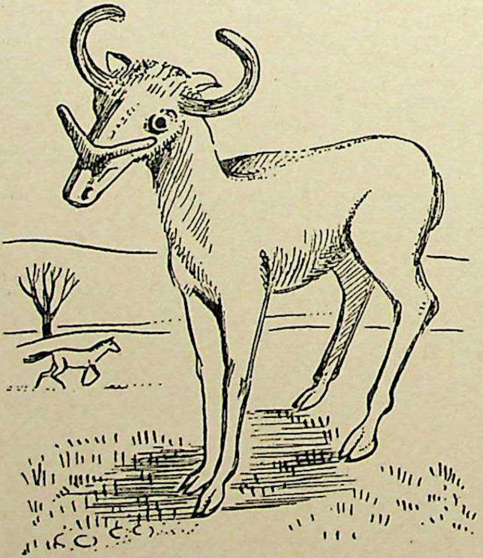

FIG. 29. Be sorry for Syndoceras!

CHAPTER VIII

The Primrose Paths

BEFORE exploring the mammals' wanderings down enticing byways from the strait and narrow path we must do some tidying and connecting with what has gone before. It is important to realize what the mammal has won from life.

We left that comparatively successful vertebrate the fish in his 'dull' world, his shadowy world of water-borne and water-obscured impressions and his correspondingly imperfect senses. By the middle of the Cainozoic or Tertiary Era there are appearing the truly modern mammals. And they have as it were won in their bodies a basic efficiency. They eat, they breathe, they digest, they grow, all these with great success; their metabolism, their muscles, their body-machine working on the excellent vertebrate ground-plan, all are efficient. But there is more to it than that. Within the warm body the nerve messages are attaining a speed and a consistency of speed that they have never attained before. The new-born babe—and the marsupial is now left far behind now, to survive only in isolated and competition-free Australia, and to a small extent in less permanently isolated South America—the new-born babe, staying in its mother's womb, enters the world in a state much more mature and thereafter thrives within the immaterial walls of its mother's protection.

All this leads to one thing: brain is being given its great chance. But not we must remember the brain that 'thinks' as we understand thinking, that cogitates, reasons, remembers: that hardly exists yet. We forget how much else the brain does. The water-brain, the primitive fish brain, is in this Era changing to a refined and accurate interpreter of the outside world by means of the senses and at the same time a powerful commander of a well coördinated body acting in response to those senses.

Sight is becoming long and keen, though not yet stereoscopic nor, probably, colour-conscious; hearing is growing acute; touch, linked up with the refinements of sex, is coming to mean much more to life; smell is coming to mean a very great deal indeed.

That last is perhaps surprising. Indeed if we think about it, that there should be such a thing at all as smell is surprising. For our sensitivities can only have evolved as a reaction to the physical world —even our sense of rhythm and tone, that is to say of music, can be no more than that. And whereas if we could have been asked what senses *would* evolve we feel we might well have guessed at sight and even hearing, the idea of smell, the idea of being able to react, by means of a mere damp portion of our anatomy (the inside of our nose) to infinitely small particles settling thereon, and in so subtly discriminating a way, is really rather extraordinary.

But there it is; the mammal, finding this fishy mechanism of the waters surprisingly more potent in the air, goes ahead to make the most of it. The mammal creates smells, responds to smells, half lives by smells; the smell-distinguishing part of his brain grows enormously in size and relative importance. So in many species does the smelling organ: the snout.

That in fact we might call the first aberration, the first straying from the path of progress towards mere specialization. Smell is a very useful sense: it can pick up its message round corners and without a turning of the head. But it never tells you very much, it is capable of no great refinement; it is not only because we have largely lost it that we humans set so little store by it. A dog, as G. K. Chesterton says, may well be able to distinguish the brave smell of a stone. But *we* can take that stone up, and break it, and admire the beauty of its chipped surface—and find a use for the chip in the shape of our first tool. Nor need we go so far ahead to point the moral. The keen smeller is a follow-your-nose animal, often a nose-to-the-ground animal. That does not encourage use of the eyes. How awkward it would be if like our dog we had to run up to our friends and sniff before we could recognize them.

Speed is a prize to be sought. In the waters the fish won that prize, its body becoming a streamline compact of muscle and its control of those muscles highly efficient. Even so, all that must surely be child's play compared with the production of limbs that can run —an unobvious and curiously artificial mode of progression—and the control of balance and timing and coördination of muscles that that running entails. After clambering out from the sea Life obviously experienced a retrogression in this matter of speed, as it did in the matter of keeping lively and even-temperatured. The big reptiles floundered or stumped or waddled—or in despair went back to the sea. The little reptiles ran, and some of the bird-like, long-legged, middle-sized ones did so too. But they probably never ran for long at a time; no modern reptile makes that sort of sustained effort. Though they are not fat they are like a fat man in that respect: they would, with their lack of thermostasis, grow much too hot if they tried.

It was left to the horse tribe in particular to specialize in speed. The cooling of the Earth called forth the grasses and the prairies, and the prairies as it were beckoned the horse: 'Grow! Stretch out those long legs!'

There is danger in this sort of animistic fancifulness, I know. But so long as we do not let it run away with our scientific sense it has its points. Gerald Heard, in a book called *Wishing Well*, has let himself go in fancifulness, so that the evolving animals talk and the specialists boast and swagger while the little shrew-like, lemur-like, monkey-like creature has the last laugh. That sort of treatment is perhaps safer, since the fancifulness is so obvious. Let us remember in this chapter particularly, that we have no grounds as yet for ever presupposing evolutionary purpose in the individual. . . .

With that warning given, we may proceed. The horse has indeed much to be proud of: he is a miracle of speed and stamina. Nor for that matter need we deny the individual horse supreme delight in going like the wind across the plain. The horse is a great success.

What then has the horse lost in adapting itself so well to life on the prairies? It will never have an arm, a paw, a hand; it will never stand upright (except in the circus), it will never climb a tree, it will never pick anything up. It has also largely lost its weapons, and that without a man's compensating increase in brain. Its teeth in its long head have become a very special grinding machine, for grass is tough; and it certainly has no claws. Its main weapon is an avoiding one, speed in flight, so much so that it has produced that prodigy, a babe that can run almost at birth. Finally there is one other disadvantage that the horse shares with his fellow grazers. There is no great nourishment in grass; one needs to eat a tremendous amount of it to live. Many of the ungulates have invented the double stomach and the double meal, 'chewing the cud', and—to give themselves as it were a little rest and comfort—the second meal can be taken lying down, and if necessary in a safer place. Our modern cow spends of necessity almost the whole of his waking life in grazing or chewing.

Is it better then to become a flesh eater? Certainly, so long as game is plentiful, for one feeds much more quickly and has a corresponding increase in spare time. But as Arnold Bennett once asked of a road-hogging friend who proudly saved ten minutes on the journey: 'And now what are you going to do with it?' The carnivore spends it in sleep.

In fact to be a successful hunter one must be thoroughly groomed for the job. It is not only a matter of claw and fang and, as for instance with the cheetah, long legs to match your quarry's long legs. Your whole body becomes adapted, its chemistry, its condition. The mind too. The carnivores in the Age of Mammals certainly outstripped most others in development of brain, in quickness and in cunning; they must be given credit for that. But they outstripped the others in ferocity too. The big cats—and they were some of them very big—are virtually killing machines; they have two extreme conditions, and little in between: rage and lethargy. There is of course the tale of the sabre-toothed tiger, who grew longer and longer in the fang and wider and wider in the gape until he defeated his own object and became as much an absurdity as some of the over-horned and over-antlered creatures that were his quarry and with them disappeared forever to live only as a warning in the fossil record, the text-book and the museum.

Yet that last is only an extreme. The carnivore as a whole is a success. He has grace, as the horse has speed; he has little to fear; he has brains. Nevertheless, the price is great. He sniffs the breeze, or he sniffs the ground, and his body is tied inexorably to an automatic response. The two ways of doing the job seem, incidentally, to produce two very different types of animal: John Gloag once wrote a phantasy in which Evolution growing tired of the human race passed on the crown to the cat tribe; others would see more hope for the world in the social instincts of the dog. Neither eventuality however seems very probable. And finally one point of significance about the carnivores. Since with their dim wits and their love of the warmth of the sun the reptilian flesh-eaters are not likely to have prowled in the dark, we must presumably thank the warm-blooded hunters for the habit of so many mammals of sleeping by day and coming to life at night. It seems an essentially unnatural thing to do.

One animal has given its name to a deadly sin: Sloth. The giant sloth—probably not so long extinct, for in the Natural History Museum you can see a piece of his actual fur—is so good an example of life charging up a passage marked 'No Thoroughfare' that we will reserve him for a later chapter. But his later and smaller counterpart, the tree or two-toed sloth, is no more admirable. He has chosen the very negation of living, he is the passive resister *par excellence*: hang yourself up on the bough, let the moss grow on you, and the hunter is likely to pass you by—and even if he doesn't your reactions are so dull that you won't feel very much. The lumbering bear, though he is not to be compared, also took something of a backward step as through the second half of the Tertiary Age the Earth became colder and colder. He went back to the reptilian habit of letting the cold make him lethargic. He resigned in the battle to keep warm, found a cosy corner, and became unconscious till the Spring. The hibernation of mammals is an extraordinary thing. It is much more than a mere going to sleep; the pulse rate falls, the body's temperature falls; the breathing slows: by only a hair's breadth does the animal seem to hang on to life.

It would be possible to go on for some time counting the wrong turnings of the mammals, the tuskiness and pillar-like legs of the mammoth or elephant for instance, which make it as it were in desperation stretch out its lips and then produce a clever but rather poor substitute for nose-and-hand. But though we have registered a disclaimer, nevertheless to continue on this line does rather smack of complacency. Two more types only must be mentioned, and with both while pointing out their losses we can give unstinted admiration at the ingenuity and success of their command of the way of life they chose.

One kind chose the air, and the other the sea.

In fact more than one chose the sea. The whales and their lesser cousins the porpoises developed first, from what sort of primitive animal nobody knows; then later came first the seals and their kind, from a carnivore stock, and secondly, from some grazing animal, the sea cows—on to whose great shapeless shoulders someone has incredibly planted the responsibility for the mermaid myth.

For life to go back to its nursery of the waters is indeed something of a retrogression. But practically all forms of life have done it, insects and birds and mammals as well as reptiles and a few amphibians. The reptiles either assumed a wholly streamlined and fish-like form or else turned their limbs into paddles. The whales and the sea-lions did respectively very much the same thing. But it is particularly in overcoming so successfully the disability of possessing a body conditioned to air breathing and air pressure that these animals have been so admirably successful. Both seals and whales dive in search of their prey to depths that would kill us even were we to be able to 'hold our breath' for the time they remain submerged.

But they have lost a good deal in making their choice and succeeding in it. Obviously they have lost arms and legs and hands and feet. They have had to encase themselves in blubber to be able to retain their birthright of warm-bloodedness. And with the whales at least, who have made the most complete adaptation, it is as if with such inherent unsuitabilities to overcome they had to out-Herod Herod and go to extremes to beat the fish at their own game. The killer whale is so ferocious and voracious that he has been seen to kill himself by engulfing too rapidly too many of his fellow seafarers. The whalebone whale on the other hand, adopting the favourite feeding method of half the primitive life that preceded him by millions of years, ocean-swallowing or soup-straining, has turned his mouth into a sieve. That leaves him with no limbs, no teeth, no weapon of any sort. If he engulfs by mistake life that is fiercer than plankton, it will literally be the biter bit and as his mouth is torn to ribbons he will have no defence.

Finally there are the bats, the only mammal that has completely mastered the air. Though many people cannot abide these creatures, and though indeed their faces are very ugly, there is something endearing about the bats. They are small, and they are very clever.

Five times the air has been conquered : by the insects, the reptiles, the birds, the bats, and man. Man did it artificially, with the aid of his brain. The other three vertebrates did it by hand and arm. Pterodactyl left three claws free and stretched a membrane from an enormously long little finger to its leg ; the bat leaves only a clawed thumb free, and otherwise does much the same ; the bird alone leaves its legs free to act as legs—which gives it the great advantage. Whether the pterodactyl was similarly incommoded nobody is likely to know ; but the bat not only cannot walk on land at all but in many species has to hang himself upside-down by his thumb-claw when he rests.

The inducement to fly must have been the reward of food that it gave ; bats are insectivores become adventurous in chasing their prey. This has had two significant results. Insects, or at any rate the insects the bats prefer to eat, fly mostly at dusk or dark and exist hardly at all in a winged state through the Winter. To be able to fly in the dark the bats have developed a rapid and high-pitched squeak and also the most amazing sensitivity to sound vibrations ; they have in fact invented the guidance-by-echo principle some millions of years before man thought of Radar. But their second adaptation is perhaps not so clever, for to subsist through the wingless winter they have done what the bear and the hedgehog have done and resorted to hibernation. With curious and unexpected breaks of a few hours or days now and then, they hang themselves up in cave or belfry and send themselves into that queer cold trance that keeps the spark of life alight, but only just alight, until the earth slants back towards the sun and the insects too crawl out of their trance and spread their new-made wings.

And now finally: the way we have called strait and narrow because those following it have avoided the temptation of particular specialization and more immediate benefit. This will be treated summarily here, for a double reason. It is said to be the road that leads to man; and that is the most controversial statement in all the theory of Evolution and merits further treatment. Secondly it is said that the hopeful traveller reached his destination by reason of one acquisition successful above all others, brain; and so before we seek to understand the sort of brain that led to man it will be well to consider other manifestations of the miraculous stuff in insects and birds.

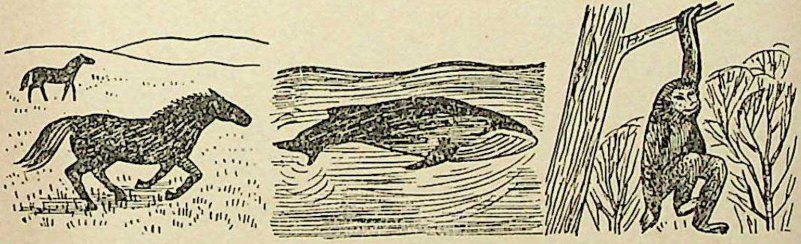

FIG. 30. Mammalian specialists

The records of the rocks present us with a small shrew-like creature, rather like the present tree shrews, as likely to have been the father of the primates. It was unspecialized, with neither the long claws of the professional killers or the fused fingers of the professional trotters. It could, and presumably did, climb trees, firstly to keep out of the way of the dinosaurs (or perhaps rather the comparatively small reptiles, since one can hardly imagine a tyrannosaurus noticing a shrew) and secondly in order to find the kind of food, grubs and insects that it either liked or learnt to like.

The need of that kind of animal would be to grow in size. This is a matter of the happy mean, and again of the difference between increase by three dimensions and by two, by cube as opposed to square. Smallness for a warm-blooded animal is perhaps even a greater disadvantage than hugeness, because the area for dissipation of heat is so much greater in proportion to the volume of the body. The small mammal's rate of living, its metabolism, is very rapid: hold a mouse in your hand and feel its heartbeats! And the modern shrew is for some reason—for he is not the very smallest of mammals—particularly cursed in that way. Leave it without food for so short a period as twelve hours, and it will die. Here is another animal that has given its name to a human failing, and again the imputation is not wholly unjustified. The shrew leads a *worried* existence in the effort to keep alive; like Alice's rabbit he is always late—for the next meal. His cousin the mole suffers the same disadvantage though perhaps not so acutely since he burrows to keep warm; but if mole meets mole in the business of burrowing there is said to be usually a fight to the death, a pointless fight since there is surely room for both under the earth.

However, the important thing about the primitive tree shrew, as opposed to the little sharp-nosed animal that squeaks and fusses in our hedges and ditches, is that he was up a tree. Undoubtedly the tree-tops are a great educative environment. They may give you safety from the great land animals, but it is not an armchair safety. The tree-top is an adventurous place, and you will be an active and adventurous animal if you are to exploit it—exploit it with your good hands for climbing and your good eyes for jumping.

Such animals still exist, and can be seen in most Zoos: the Galago or Bush Baby, the marsupial Koala, the Kinkajou and Potto, the Spectral Tarsier. Incidentally, and surely with some significance, they all make intelligent and endearing pets; they are immediately *likeable* animals with none of the ferocity of the big carnivores nor the unfriendliness and mixture of dull placidity and dull rage of most of the ungulates. But what is of real significance is that they do have real hands, and enormous eyes. Their snouts have receded and they no longer entirely follow their noses; their eyes are in front so that they have achieved what is called stereoscopic vision, using both eyes to focus on the one object and gaining finer judgment of distance thereby. The Tarsier with his very long thin fingers, ending in sucker-like pads, and his quite enormous eyes, is more an example of another good animal gone wrong and succumbing to over-specialization than an animal on the right road. Perhaps the big carnivorous prowlers at night are responsible for those eyes.

But it is not only hand and eye that should be coupled as instruments of progress; it is rather a trilogy, hand, eye and brain. For an organ of sense is of no use and in fact cannot develop in separation from the parts or elaboration of the brain that interpret its messages and make use of them. Better hand and eye will lead to better brain and better brain will make for more intelligent use of hand and eye.

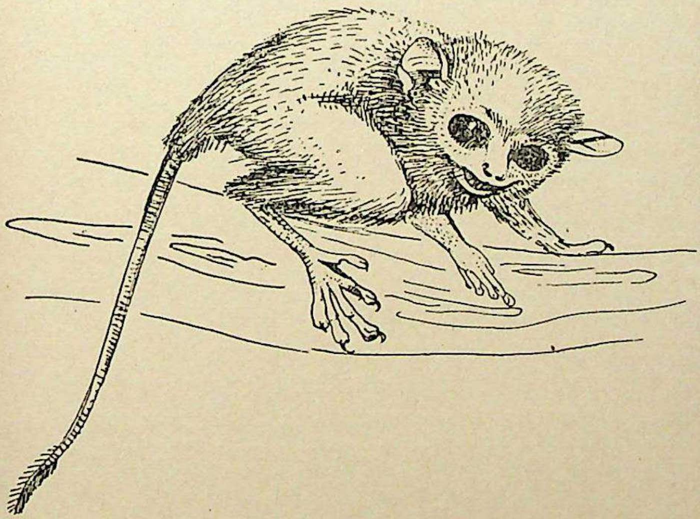

FIG. 31. The tarsier

The lemurs come next in the story. These certainly have good brains and great skill in the trees. They are also on the whole a larger animal. There is one thing they do, that in fact their predecessors may also have done, and that is to prefer to carry their young about with them rather than hide them in any sort of nest. The hand is proving useful again, the small hand clinging to the mothers' fur. It is surely reasonable to see there the beginning of greatly increased mother love.

And so to the monkeys. Now we may not like the monkeys, or they may seem merely pathetic to us, or they may seem too horribly human. But the fact remains that they have great intelligence, and also deep feelings. To return to the idea just expressed, of mother love: a monkey pets her baby, strokes her baby, fondles her baby. It may be all merely physical; but who can divide physical from spiritual or deny the influence of the one upon the other? Then the monkey really uses his hand, uses it for much more than mere climbing. He takes things, he throws things, *examines* things. That is the monkey's great asset: curiosity. Perhaps that in fact is the attribute in which he has finally specialized too far, that and an acrobatic facility. Watch a spider monkey, all long wheeling arms and prehensile tail. The main line has got to do better than that.

The main line, it is believed, fathered both apes and man. Apes, it is held, retrogressed from it; Man progressed. Apes, with one partial exception, stayed in the trees, that partial exception being the gorilla, who has merely taken another wrong turning, towards ferocity and muscle, so that neither trees nor his own legs can bear his weight with any ease.

Man's predecessor, it is believed, had the courage to come down to the ground again. He developed from what had become virtually a four-handed animal back into one with feet. And at the same time he learnt to walk upright. His hands were freed. He put his trust in them, and at the same time sacrificed his jaws as a weapon. The reward was control of tools, control of fire, and speech.

So, over-simply, we will now put it. There is much to question in these statements, and when we have surveyed more of the animal scene we can come back to them.

CHAPTER IX

Wings and Instinct

WE left the insect as some primitive scorpion-like arthropod, perhaps not yet wholly air-breathing and established precariously as it were on the mere brink of the dry land. That was in Paleozoic times, before the coal-age forests, before the amphibians and certainly before the reptiles. Insects have gone a long way since then, so that they now populate the Earth in far greater numbers and variety than any other species. Their success is considerable—and their habits are amazing. We shall do well to look more closely into their evolution.

We have already said that the problems facing their forbears ere they could flourish independent of the sea were not so great as for the vertebrates and that they succeeded in oxygenating their bodies in a very simple way. That ingenious method, of tracheae or fine air tubes penetrating the body, needs now to be considered a little more closely.

Insects' blood carries around to the parts of their bodies, as does our blood, the digested food and the 'chemical messengers' or hormones. But it does not carry—indeed, colourless as it is, it does not possess—the oxygen-bearing red corpuscles. It does not need to do so for the reason that the insect possesses this starkly simple method of the tracheae penetrating all parts of the body from the outside. It has but to pump air in and out of these tubes by means of rhythmic movements of the body—this can be seen very plainly in wasps—and by direct contact and diffusion its tissues will be oxygenated. They will be oxygenated that is to say, so long as there is no great bulk of them ; this is an efficient system *only in miniature*. In nowhere but our nightmares in fact—and we may be thankful for it—will insects ever rival us in size. They may be long and thin, they may have expanse of wing, but in bulk and weight they just about leave off where the smallest mammal begins. There is great significance in this necessary smallness of insects and one particular significance that will be borne in upon us as we proceed with these two chapters.

But to be small and of little weight is not all disadvantage. It seems almost inevitable that insects should be the great conquerors of the air. There are modern insects that have let their wings atrophy —the flea is one—but there are others, the springtails or firebrats and their equally unpleasant relations the silver fish that infest steam pipes and unhygienic bakeries, that as a species have never had wings and are much like the most primitive insects discovered in the record of the rocks. But already these creatures had settled down to the successful basic ground-plan of a three-piece body—head, chest and abdomen—and the arthropods have never found it difficult to create out of their segmented bodies any particular appendage that suited their needs, whether it be pincers or balancers, claws or wings.

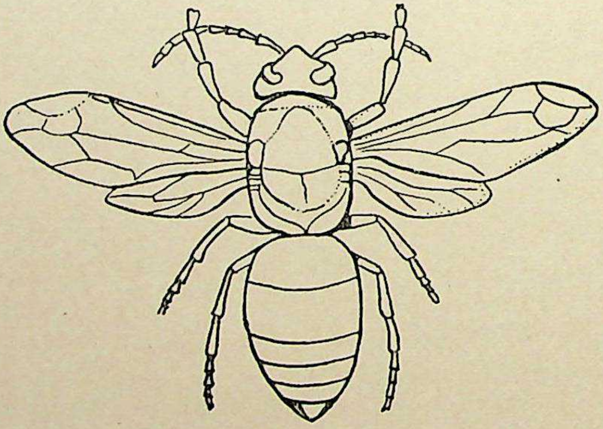

FIG. 32. The typical three-piece pattern of the insect—a hornet

Very soon therefore in the story of the insects *wings* arrived. Their owners were the pioneers in the new element, with no incentive to find food there as with their successors, for no food existed. But there must have been great advantage in being able to alight on a plant rather than climb laboriously up it : the insects, it will be noted, are rapidly to become the great vegetarians of the world, the great plant eaters and plant suckers. Another early development was the change from the possession of a generalized biting mouth to the piercing and sap-sucking kind that our modern plant bugs use to such good effect.

Now all this so far is in one of the world's warm lush periods, the long last half of the Paleozoic Era. By the time of the Coal Measures insects have reached their record span of wing : no picture of that torpid and steamy world, with its wallowing amphibia and its giant primitive trees, is complete without the inclusion of the equally primitive but enormous dragonfly-like insect with its four gauzy wings that achieved a span of over two feet. Those wings nevertheless were clumsy things, not well co-ordinated : the bee's wing is a long way off in time.

Before the bee however, and before those other three representatives of what are called the social insects, the wasp and ant and termite, there are big evolutionary steps to be mounted. First of all the insects had to survive, as did the vertebrates, the revolution of climate that with ice and desiccation ended the Paleozoic Era and ushered in the Mesozoic. The insects were never likely to achieve warm-bloodedness and in fact never have : they are too small. But the long, long summer had gone ; and they had to find some way of surviving this new threat to their existence, the hard season of Winter that comes after only a few months of congenial warmth. They did it by inventing *metamorphosis* or the changing of their bodily form.

This is something extraordinary and most significant. To say 'change of bodily form' is really a great understatement ; in many instances the transformation is so great that did we not know the truth we should never accept the second form as having any connection whatever with the first—in fact we often did not but preferred to regard flies and the like as a spontaneous generation from the decay in which their maggots bred. Imagine a childhood of ninety-nine per cent of one's life spent under water and a one per cent, of as little as one day's duration, in which to exist in the air and to use one's wings and to perpetuate one's species ! Imagine feeling in the Autumn an irresistible urge to spin oneself a prison and to lie there through the Winter whilst one's organs virtually liquefied and re-formed !

It is impossible to imagine these things. And that is really the proper way to look at this matter. Anthropomorphism, facile comparison with oneself, is a snare. What needs to be realized in considering this other kind of creation, the insect, is how utterly and completely different it is from the kind of creation to which we ourselves belong. It is not only a matter of contrasting form and behaviour ; it is that the whole conception of consciousness, of individuality, of being alive as an insect, must be utterly different from the same conception as applied to ourselves and the familiar mammals. It has to be considered afresh, and with a very real effort.

Particularly must patronizing comparison be recognized as a snare. Insects are continually amazing; it is wonderful for instance that a bee can by an excited dance inform his fellow workers of the direction and approximate distance of a discovered store of nectar. But it is not wonderful because the bee has shown himself nearly as clever as a man; it is wonderful in its own right. Insects, like men, have a long story of evolution behind them. They are often more clever than men, more successful than men, in the light of what we must regard as first principles more moral than men; but they are also often incredibly, or laughably, or sickeningly the very opposite of all these. In a word that ought to be hung up in metaphorical neon lighting in the forefront of our view, insects are *different*.

We can now return to metamorphosis. Its purpose is for insect life to thrive in a world of seasonally recurring harshness. The fully grown, winged insect will find it very difficult to survive the Winter. The programme then, as finally evolved, is something like this:

1. Be born in the Spring or Summer.
2. Eat and grow fat in the Summer or Autumn.
3. Insulate yourself and prepare yourself through the following Winter.
4. Be born again next Spring.
5. Carefully perpetuate yourself in this second Spring and Summer.
6. Die in the second Autumn.

This is a programme that is observed with much variation and degree of thoroughness, but that is the basic idea. It is an idea that could surely not have been worked out for any other form of life than the arthropod because already the arthropod has developed that capacity to moult. In order to increase in size he must cast his external skeleton and grow a new and bigger one. The insect goes further; he not only grows but changes. And how he changes!

It is useful to have before one the names that are given to these various changes of state, for it is then easier to appreciate how there are degrees of thoroughness in this business of metamorphosis. First, to return to the primitive silver fish: he hardly changes at all, he just hatches and grows by a series of moults. Secondly there comes what is called the direct metamorphosis, where the young is a nymph and the grown creature an adult or *imago*. Cockroaches, grasshoppers, earwigs, aphides behave in this way. The young are still very like the adult but there are as yet no wings nor external sex organs. The wings bud out and grow at each moult; but once they have grown fully—and this applies to all winged insects—no more moults will ever occur.

A more noticeable change, though it is still 'direct' metamorphosis, is seen with such creatures as the mayfly and dragonfly where the larva stage is lived under water. Then—to speak unscientifically but with some point—the larva is a fish. It has gills. The dragonfly nymph and the dragonfly imago may be structurally a good deal alike, but when the nymph climbs out of the water and, with what one feels must be very necessary periods of rest, pumps out himself and his glorious wings, he is to our eyes a very different creature indeed.

Water does not freeze solid and water larvae usually live through one or even two Winters before making their great change. Once more the harshness of the world above water is avoided rather than conquered; and the grown creature will never live far from water, for the sake of her eggs.

Now for 'indirect' or staged metamorphosis, which is the habit of most of the rest of the insects we know. The young as they hatch from the egg are called generically *larvae*; the resting stage is given the name of a *pupa*, and the final result is again an adult or imago. It is a little confusing perhaps because for the generic word 'larva' there is often substituted a particular word: the 'caterpillar' of butterflies and moths; the 'maggot' of flies, and the 'grub' of bees and wasps.

There are different kinds of pupae too. The word itself is most often used for the less elaborate and drastic self-imprisonment (as with beetles where the grub does not coffin itself entirely). This sort usually seeks protection and warmth beneath the ground. The more elaborate method of pupating is to spin a cocoon. Flies as well as moths form them and often the silk is mixed with the caterpillar's own hair, or odd bits of debris, or the bark of trees. It is not for nothing incidentally that silk is a good insulator against cold. *Chrysalis*, since it derives from the Greek word for gold, should really only apply to those butterfly pupae that have a metallic sheen, but it has come to mean all that sort where the enclosure is complete and not spun. Most of them, in spite of this bright-sounding name, achieve a high degree of camouflage in relation to their surroundings —a part of their very necessary protection.

And in that quiescent state, within those coffins or those winding sheets that enclose what we may rightly call the dying larva, there is proceeding an intense biological activity. 'Not much imagination is called for,' says Mr. A. D. Imms in his *Insect Natural History*,* 'to realize the profundity of the task nature has set herself to accomplish in the transforming the sluggish leaf-eating caterpillar into the immensely active nectar-sucking butterfly.' Not only active and nectar-sucking it might be added, but a creature fully endowed from the moment of its rebirth with all the equipment for living that it will ever need, that is not, and need not, be taught a single trick of behaviour, from how to fly to exactly how and when to lay its eggs.

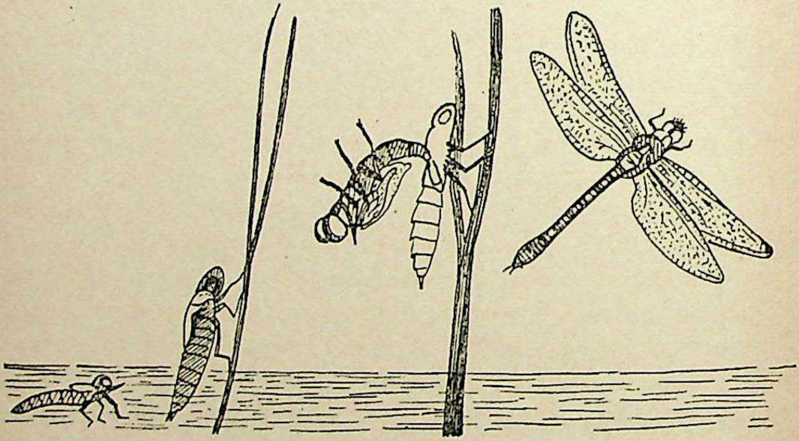

FIG. 33. Metamorphosis : the dragonfly

The perfection of this 'profound task' naturally needed a wide span of time. Through half the Paleozoic and all the Mesozoic, while the giant reptiles were lording it and then ignominiously disappearing, the insects must have been elaborating these strange and ingenious life-cycles that fitted them so well, with their small size and their cold blood, to their environment.

What else contributed to their success? The answer can I think be fairly given as two main achievements : a partnership with plant life ; and sociability. The second is important enough to merit another chapter.

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* In the Collins' New Naturalist Series.

Whether insects are on the whole of more benefit than harm to plant life is doubtful; but as pollen-carriers and fertilizers they have certainly been a help. Again, even how great a help may be disputed: some plants would probably do as well with only the wind to carry their pollen, and others, though they still have flowers, do not nowadays continue their species by means of fertilization at all. One thing however at least seems certain, that without the greediness and obliging adaptability of the insects there would have been no flowers, and without the variety of flowers there would have been less beautiful and bizarre shape and form of insects, so that we at least and in either case are aesthetically the gainers.

In the chapter describing life's emergence on to the land it was explained how the plants and trees were first half tied to water, and also to a curious and not very efficient method of self-perpetuation in which a purely ephemeral sexless generation was inserted between the sexual—nature experimenting in that way is very reminiscent of man's inventions, where the early editions seem to the users of the later ones so unnecessarily complicated. It was also explained earlier that with the flower came full emancipation from dependence upon water, the flower being described as secreting a spot of moisture, 'a small private sea' in which life's classical method of perpetuation, male element making its way to female, could be effected. It was added that the rest of the story would be told with that of the insects. Now we come to it.

The evolution of the flower from what was originally a leaf bud is long and complicated. It becomes in essence a trap for pollen (the male element) and a cup or container where the pollen can grow down to the waiting ovaries to fertilize them. Now pollen is nitrogenous and nourishing: insects no doubt helped themselves. How much better then to turn the robber into a midwife—the simile is a little stretched but it will serve—and to bribe the insect by the mere secretion of a drop of sweet water to crawl over both male and female flowers and so not only bring the pollen to where it was wanted much more certainly but also to effect cross-fertilization more often.

That is in effect what happened. The flower, it can be fairly said, is biologically one huge advertisement: 'Come here!' Not only that, but, 'Come here particularly! Stick to us! We are your favourite colour! We are the shape that fits you!'

All that is shamefully anthropomorphic—and no implications of purpose, conscious or semi-conscious, are intended. It does help to give the picture however : an amazing picture of the most elaborate interrelationship, of the most ingenious tricks, the most economical mutual help. Flowers with trap-doors, like the snapdragon, are found, flowers with enormously long passages to the nectary, as with some of the orchids. And always an insect is created that can and will serve that particular flower. The bee's furry body is formed, the moth's and butterfly's marvellous coiled tube of a sucking tongue. Before the birds and the primates carried colour, the flowers brought it into the land. Before the mammals wallowed in it the flowers brought scents on to the air—and considerably less crude and more subtle scents at that. It could be said with some reason that it was the flowering plants that brought the bees and the butterflies and the moths into existence.

Not that the insects were passive. They were taking their opportunity—as successful life always does. Flowers or no flowers they were in fact increasing their efficiency. Wings were originally clumsy ; they were perhaps difficult to furl. There arrived finally the neat wing cases of the beetle tribe, and the linked or 'married' wings of the bees and their relations, the hymenoptera, that can vibrate at a speed which for our muscles would be quite impossible.

But most of all the insects must have been improving in elaboration and subtlety of instinct. Perhaps it was their possession of an instinctive mind and not an intelligent mind that made them successful in this collaboration with the flowers : it enabled them to be so *malleable* in their behaviour.

To broach that idea, however, is really to stray into the next chapter. For it was undoubtedly that characteristic that enabled the insects to evolve into social creatures in their own peculiar manner.

CHAPTER X

Living in Amity

WOLVES hunt in packs, and many of the grazing animals herd together for mutual protection, even progressing so far towards specialization as to post lookouts and sentries. Baboons live together and observe some fairly complicated codes of behaviour in an effort to curb their quarrelsomeness and their promiscuity. But all that does not go very far. The only truly *social* animals in the world are on the one hand man and on the other the wasps and the bees and the ants and the termites.

But what different alternatives they are! Men and insects have achieved a social life from a totally different beginning, in a totally different manner, and by the use of totally different tools. It would be right to go even further and to speak of the use of *a* totally different tool. With man it was achieved by education and restraint, by the development and exercise, in one word, of a conscience—'Ye shall be as Gods, knowing good and evil.' With insects it was achieved by the exercise of instinct.

That may be a very wide generalization. But so long as it is treated as such it is one to be clearly borne in mind. It is really another aspect of this all-enveloping *difference* between insects and ourselves. In tracing the evolution of their social achievements we shall encounter not a glimmer of those reactions and emotions that men with consciences possess: compassion, decency, pity. Perhaps, you may say, we should never expect them. But at least it is significant that they are not there. Rather than be continually expressing horror at insect behaviour, let us at least register it once, and vehemently, before we start the story: insects are very often quite horrible.

Now let us be dispassionate. However it was achieved, the elaborate social life of the insects is an extraordinary thing and surely of great significance to ourselves as representing the only other form of life that has reached by so different methods a similar goal.

The first question to consider is why it should ever have happened. For answer it is probably enough to point out that insects are small, by comparison with their environment very small. You can get a lot of insects on a single plant—as every gardener knows. Then there is the matter of keeping warm, which for the cold-blooded creature is not easy: when the great cold spell came after the Carboniferous Age the insects had to seek shelter. They had also never abandoned, or at least had not greatly modified, the habit of most primitive life of producing a multiplicity of offsprings. In other words, insects found themselves naturally crowded together, and had to do something about it.

What had they to do? What was necessary for an insect society to enable it to establish and to perpetuate itself successfully? The naturalist, Mr. O. W. Richards, gives the answer very succinctly in his book *The Social Insects*, and we will follow him. The needs he suggests are four:

To control reproduction.
To obtain enough food.
To learn to be co-operative.
To learn to meet changing situations.

The first is perhaps the least obvious. Here there are two forces at play, maternal care and maternal jealousy; and they are opposing forces.

We must go back a step, to the insects that show something of what we should call family life but who have failed to become truly social. What has prevented them?

Earwigs guard their young. Fabre has told delightfully of the Sisyphus beetle, where not only the mother but both parents work with such selfless persistence to prepare a pellet of sheep dung that shall be a larder for their offspring and then push and pull and roll and trundle it over every obstacle to deposit it in just such a place as they feel to be right that they should deposit it. Then the solitary wasps—for there are many more species of wasp, and of bee also, that have not acquired social habits than those that have—the solitary wasps take also great pains to find the right food for their offsprings and to drag it to the right place. Here what we should regard as the innocent pleasure of the dung beetle juggling his pellet with pride between his legs gives place to something much more grim, the stinging and paralysing, but not the killing, of some caterpillar into whose inert body the mother wasp will lay her egg and on whose inert body the hatched grub will later feed.

But whether the process be to our eyes fond and pathetic or the height of refined cruelty is not what is significant at the moment. What matters is that that wasp mother, for all her initial care, will never see her young, and those beetles and earwigs and the rest, though they may for a while tend and protect their larvæ will not do so for long but will as a generality die as the Winter closes down on them and before their brood have even approached maturity. You cannot have much of a family life where the parents are always dying.

What is needed is not merely a warm burrow where the eggs may hatch but a warm burrow where the mother may survive and go on laying. It will help further if, as in human families, there exist nurses, or elder sisters, who will help rear the younger broods. That is just what has happened. But the way was not easy, for there arose the difficulty we first spoke of : the disruptiveness of sex, the jealousies of wives and mothers.

There is nothing coy or amusing about this, a sort of insect equivalent of the mother-in-law joke. It is grim fact that even in the most intelligent of social insects the mother, the queen, will seldom easily brook a rival : the whole history of bee and ant and termite is shot through with regicide, with the death of Infantas, with queens biting off each other's heads. Yet they manage ; the great social units are formed. What, we may well ask, is the invention that has made it possible ?

The answer is, the sterilization of the vast majority of daughters. You have then these creatures with the instinct of the nursemaid but the inability to be a mother : no queen need be jealous of them.

That was an extraordinary but a most successful invention. It was coupled with a capability on the part of queen ant or wasp or bee which will seem to us equally bizarre, the power of parthenogenesis or virgin birth. Not only that, but this power can be turned on or off at will. Once the queen has been impregnated with the sperms of the mating male she can release or not release those sperms at will as she lays her eggs. And the parthenogenetic eggs will turn into males and the fertile eggs into (usually) the sterile nursing females. There only remains the creation of new queens, so that the community may be revitalized or may increase and branch off into new communities. Whether that is achieved purely by the special feeding of the female grubs chosen to have royalty thrust upon them, or whether the cause is more subtle and less material no one can yet say ;

but at least the reigning queen does not shrink from the creation of these rivals that may cause her removal or her death and dutifully gives birth to the males that will with even greater devotion serve their purpose of fertilizing and then die.

We come now to the second need.

To obtain enough food is perhaps not difficult for at any rate the termites who mostly live exclusively on wood, having welcomed certain protozoa into their interiors so that they can digest the otherwise indigestible. But for the other social insects food is a very real problem. Indeed to become successfully social they must have had largely to change their feeding habits. Originally it seems likely that all the insects that later became social were hunters.

Now though we deplored the over-specialization of the cat tribe that led to such exaggerated hate-machines as the sabre-toothed tiger we had to admit that a hunting life seemed to increase intelligence. Perhaps the same is true of the insects. However, that is not the whole of the story. The hunter's life is a precarious life. Man did not become a fully social animal, that is to say did not achieve civilization, until he had abandoned a dependence upon hunting in favour of the life agricultural and pastoral and had been able to create a store or reserve of food. The social insects, in varying degrees and ways, have had to do exactly the same thing.

The social wasps have only half turned to vegetarianism. Like Baby Bunting's father they hunt for the benefit of their children. They will take home carrion; but they also seize and kill smaller insects. The terrible need of the solitary wasps to supply a living larder for their lonely and unattended grubs has disappeared, so that social wasps reserve their sting for those that disturb their homes. But the fate of the unwary insect that is pounced upon is no less sure and hardly less grisly. He is killed, cut-up, and masticated into a sort of meat paste; and on that the wasp grub is fed. Now though this may be contrary to a sentimentalist's way of thinking, it is the baby and not the adult of most forms of life that most needs flesh food; to produce flesh from flesh is easier than flesh from grass. Fabre pointed this out after discovering that Ammophilia, the bee-hunter, is not being greedy when she sucks the honey from a bee she has killed but is on the contrary exercising an even greater solicitude for her young, since though the bee is good food its honey would be so indigestible that the larva would die rather than eat it. Mammals have of course a kindlier way of giving protein, flesh-food, to their young, by the making of mother's milk.

The wasp in its adult stage has become, so far as feeding itself goes, entirely a vegetarian; in fact it has become almost entirely a drinker, its gullet being too narrow for anything else. Beside sweet fruit juices and the like it sucks the honey from a few flowers. It also gets a sweet drink in another curious way, and as a reward for feeding the young. This is a sweet saliva that oozes from the mouth of the grub and that is licked up by the worker and supplier of the masticated meat paste: By just exchange one for the other given.

In fairness it should be added that some naturalists think that this licking of grub-saliva is merely a hygienic operation, a mere tidying-up process. For whichever reason however, it is true that the social insects are great lickers-up of salivas, great exchangers of partly digested food and even users of the final products of their bodily processes. Like the Chinese peasants, they waste nothing—though conversely, and like shall we say the pet dog, they do seem often very greedy, sometimes to their undoing as we shall see when we consider the ants.

The bees have taught their young to subsist on the protein of pollen and the sweet calories of honey—itself a partly digested product. They have reaped the advantage there of a food that can be stored, and so we come to the first obvious parallel with man's means to civilization, the creating of a store and a surplus. The bees are the great, the indefatigable honey gatherers, and the hive bees—there are many more species of solitary bee than hive bee—have, with the moths and butterflies, kept pace in that evolutionary race with the flowers, growing longer tongues to gain the reward from the more difficult and exclusive nectaries.

It is not only in the storing of food that hive bees have achieved success, it is also in their tireless energy and selfless zeal in gathering it and their mutual help in finding it. A bee will have flapped its wings—if 'flapped' is the right word for a process that is performed at the rate of 250 to the second—anything up to about eight million times in one journey to and from the hive. It is however the power to pass on information—the power to *communicate*, so essential to any civilization—that is the bees' greatest triumph.

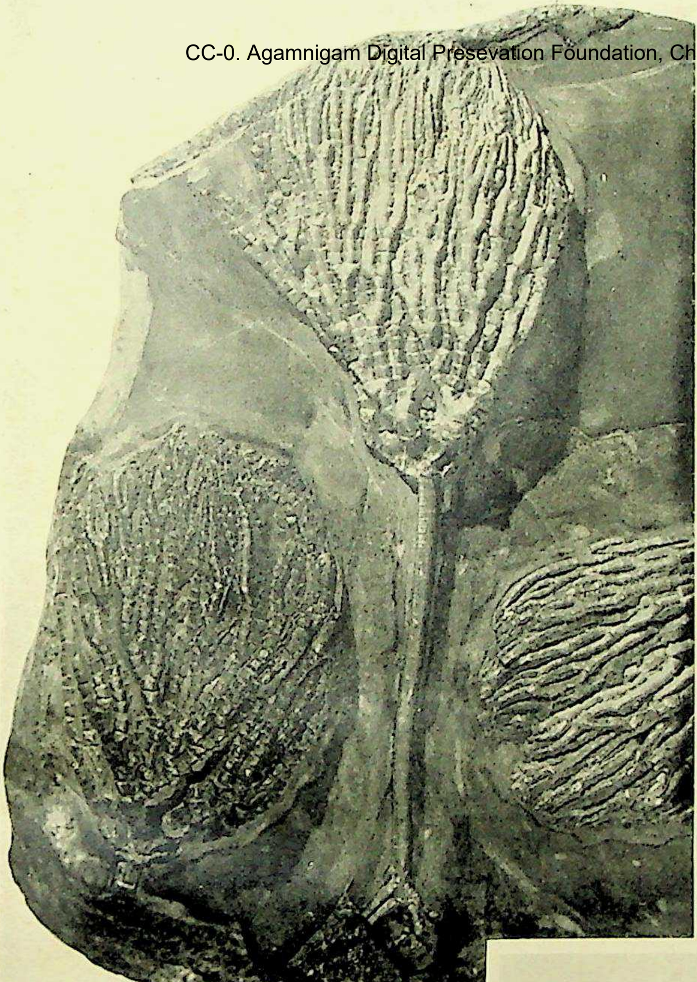
An Austrian, Karl von Frisch, is the discoverer of the bees' 'dance language', and his at first scarcely credible claims have been corroborated by other experimenters. There are two kinds of dance, one where the discovered source of food is less than about a hundred yards away and the other where it is more. The first is simple, with the bee running round a circular track first one way then the other. This, one might say, means, 'Nectar found near.' Since the bee will also have marked the source with her own scent gland, and may also for that matter carry to the sensitive organs of her fellows the scent of the flower she has visited, the search will not be difficult and no direction pointer is needed.

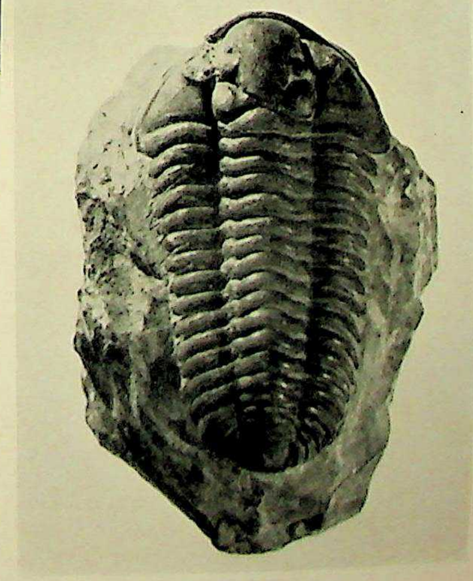
But for longer distances the story is different. The dance now becomes a flattened figure eight, with the cross-over elongated into a short straight path. Each time the bee traverses this path she wags her abdomen. And the further the distance to be indicated both the slower the dance and the greater the number of waggings.

But direction still has to be given. Sometimes this dance is performed on a horizontal plane outside the hive. Then the 'straight walk' is made simply to point in the right direction. But more often the dance floor if vertical, on a comb, within the hive. Then an exactly vertical 'straight walk' will indicate that the discovered supply of nectar is in the direct line of the sun and any angle at which the walk is made will signify a direction at a corresponding angle. The question arises, what happens if there is no sun visible. The answer is surprising. If the sky is totally overcast then the bee is defeated : there is no dance. But there only needs to be a patch of blue sky and the dance is correctly performed. The explanation put forward is that the bee possesses another of those sensitivities, such as the pressure-sense of fishes, which human beings do not possess at all. This time it is a sensitiveness to the polarization of light or the emission of light in one plane rather than its normal broadcast. The degree of the polarization of the sun's light from the patch of blue sky will vary with the patch's distance from the sun ; and there is no other explanation other than that the bee is aware of this degree.

The bee, for all her cleverness, is nevertheless neither agriculturist nor pastoralist ; she is one might say a vegetarian hunter with a flair for co-operation. The final step is reserved for the ants and those few species of termites that are not tied to an exclusive diet of wood.

The bee with its furry body and gossamer wings, its companionship with sunny hours and evocation of the beauty of flowers, is to man a sympathetic creature. Not so the insignificant and inimical ant. It is difficult to appreciate therefore that the ant, black, red, brown or 'white', is in many ways the cleverest and most highly



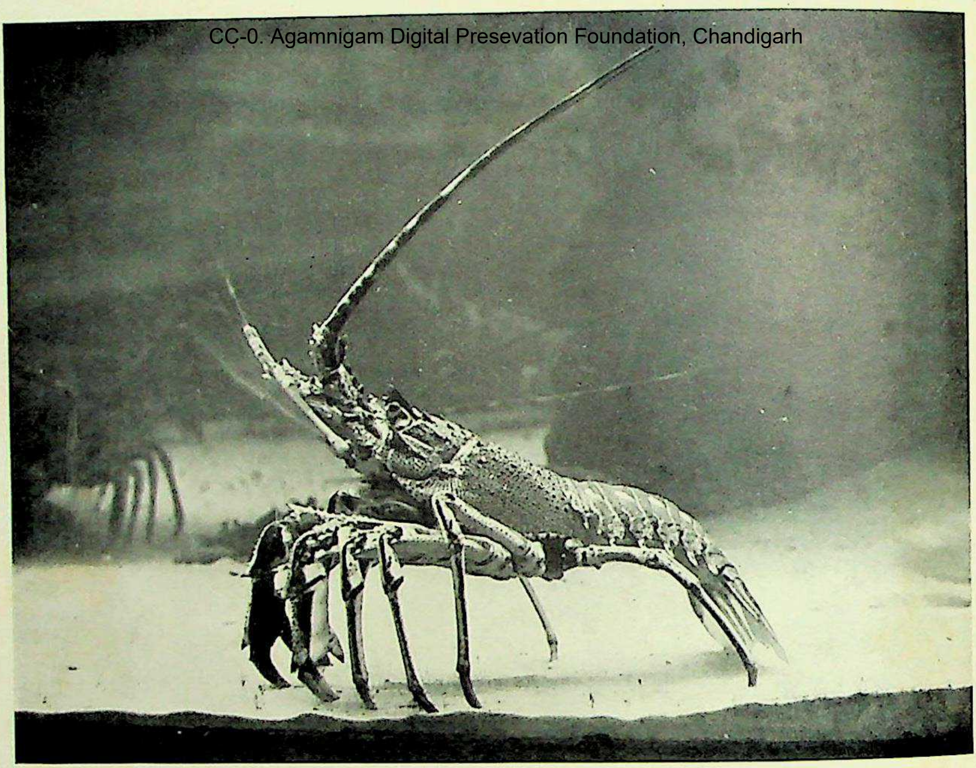


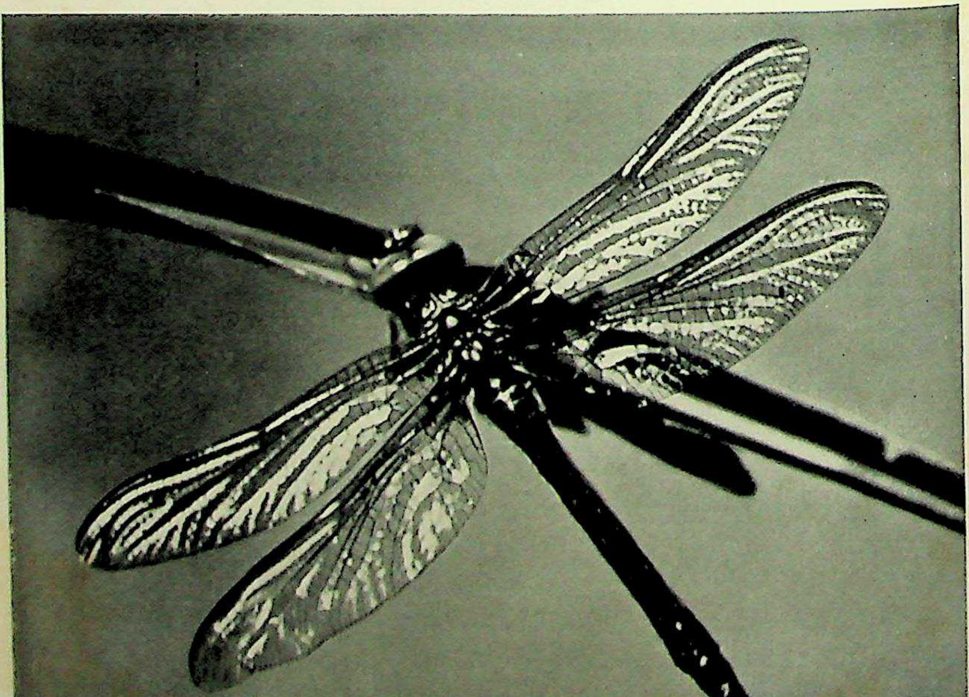
Photos : British Museum

These sixteen pages of photographs are chosen to illustrate what might be called a very elevated bird's-eye view of the course of evolution. The jumps, especially at the beginning, are pretty tremendous

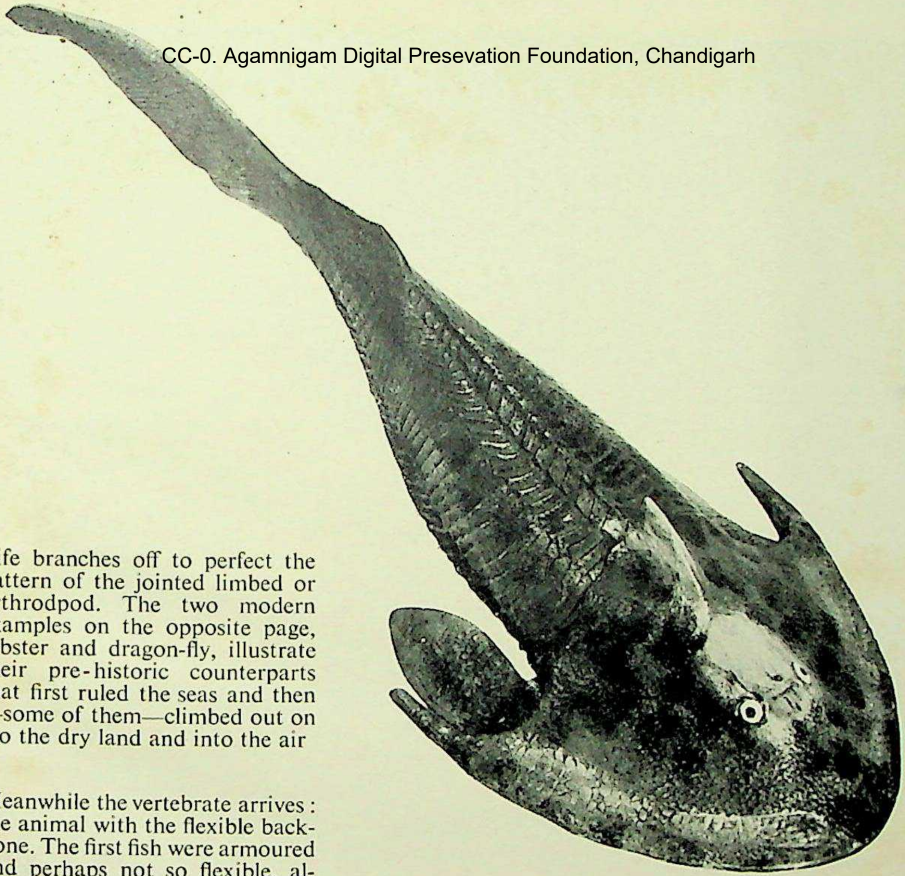
Above is Crinoid or Sea Lily, typical of animal life that rooted itself to the rocks and waved itself blindly and with a no doubt deceptive laziness in the warm seas of more than 400 million years ago. It belongs to the phylum echinoderm, believed to be the most likely line from which we and all the vertebrates arise

With trilobites, life has at least achieved a flexible body, a head-end, and the ability to burrow, crawl and (rather inefficiently) swim. The one shown on the right is 2½ in. long, a little above the average



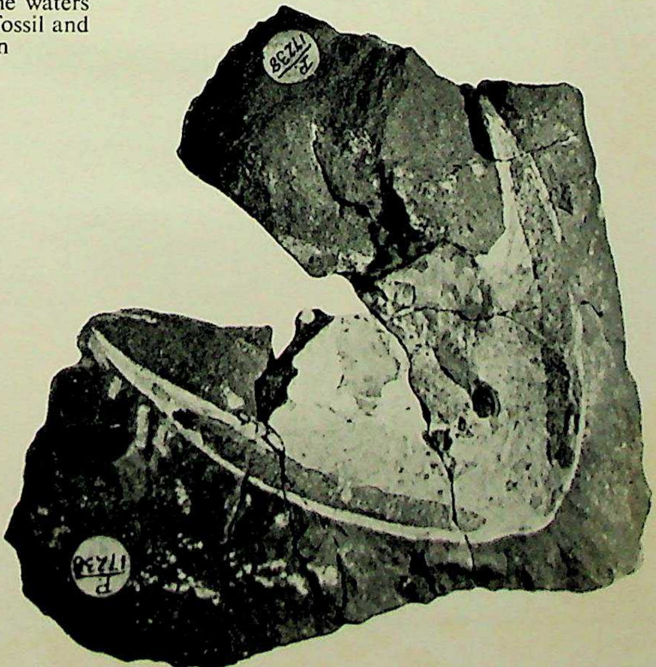


Photos : The Zoological Society of London



Life branches off to perfect the pattern of the jointed limbed or arthrodpod. The two modern examples on the opposite page, lobster and dragon-fly, illustrate their pre-historic counterparts that first ruled the seas and then —some of them—climbed out on to the dry land and into the air

Meanwhile the vertebrate arrives : the animal with the flexible backbone. The first fish were armoured and perhaps not so flexible, although almost certainly the most skilful swimmers that the waters had yet seen. Here is a fossil and its reconstruction



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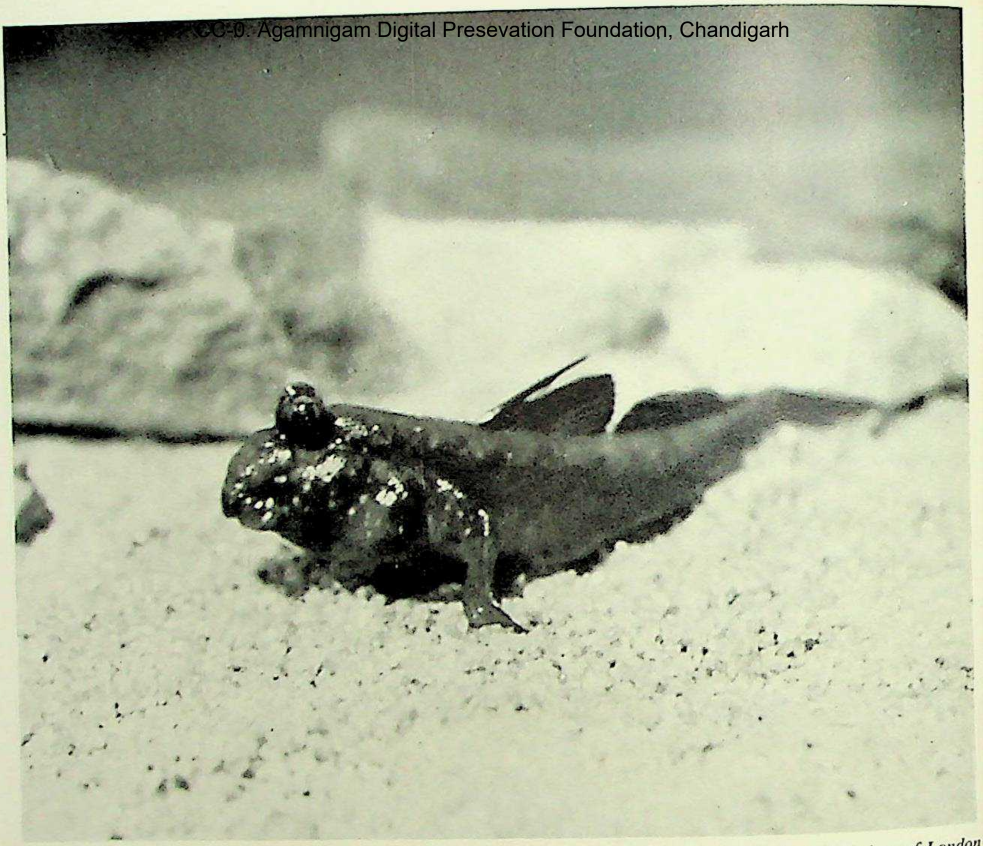


Photo : The Zoological Society of London

Necessity is the mother of invention; and in a world that is becoming less watery the fish's necessity may have been to waddle to the next pool before its own had dried up. By some miracle it transformed its fins into legs. This photograph of a modern mudhopper shows how it was probably done

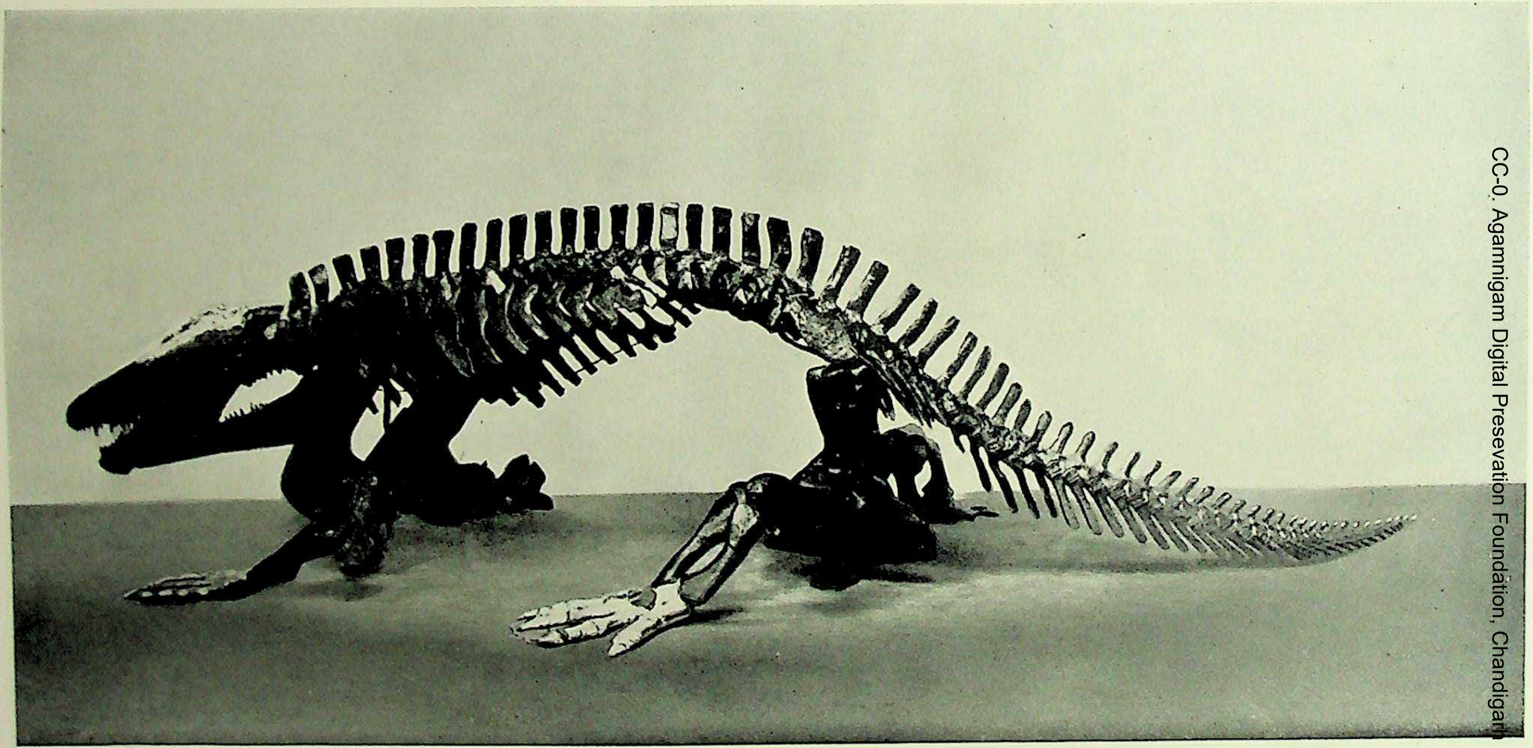
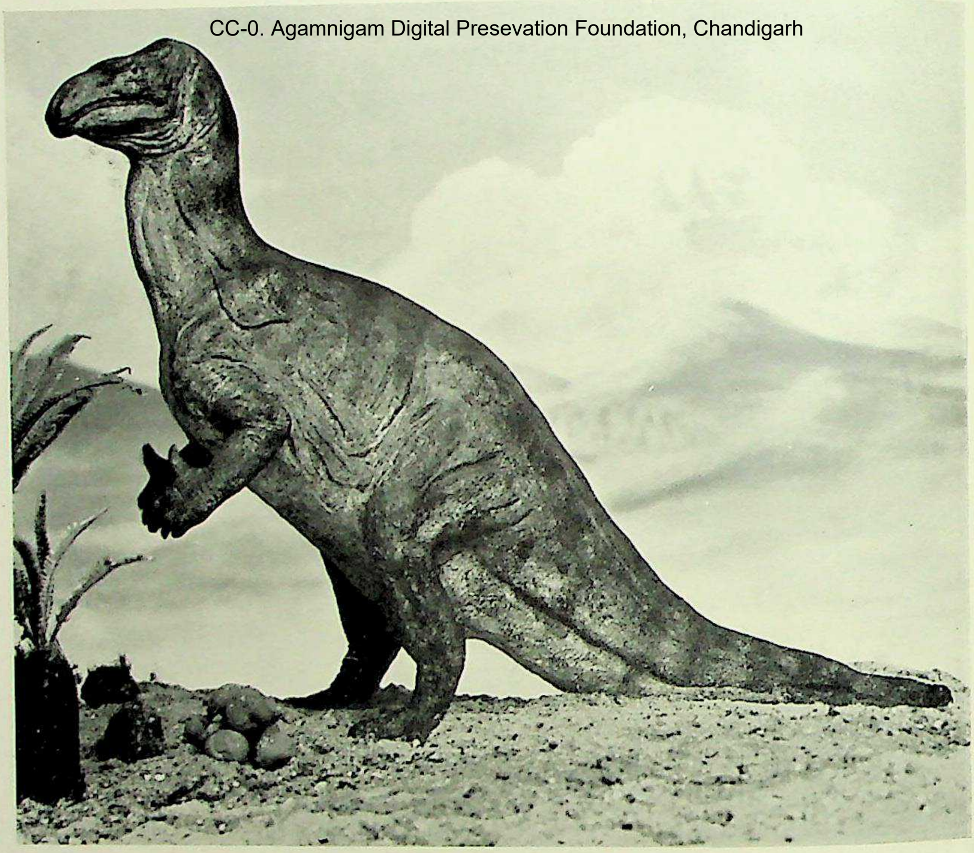


Photo : British Museum

Life, climbing on to dry land, grows big. This fossil amphibian, *Eryops* (scientific Greek for 'drawn-out faced') is just over five feet from tip to tail. He was probably a flounderer rather than a runner and, like his modern equivalent, was still dependent upon the presence of water for comfort, existence and propagation

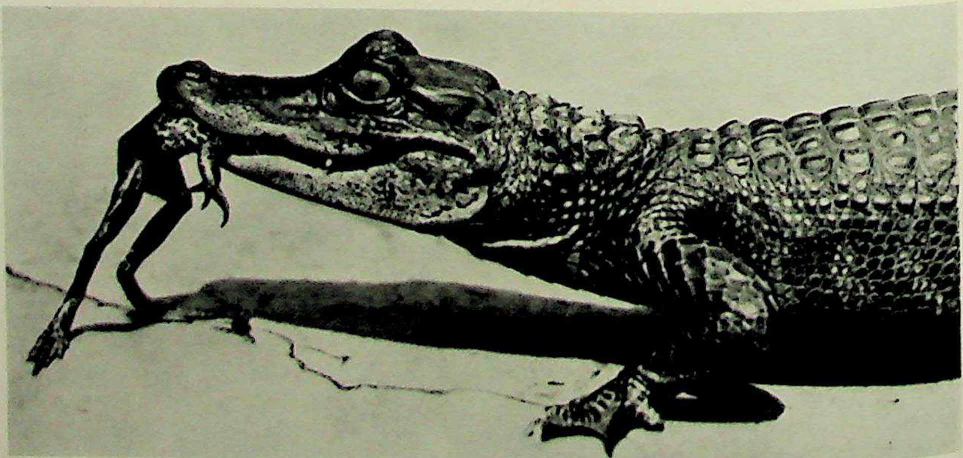


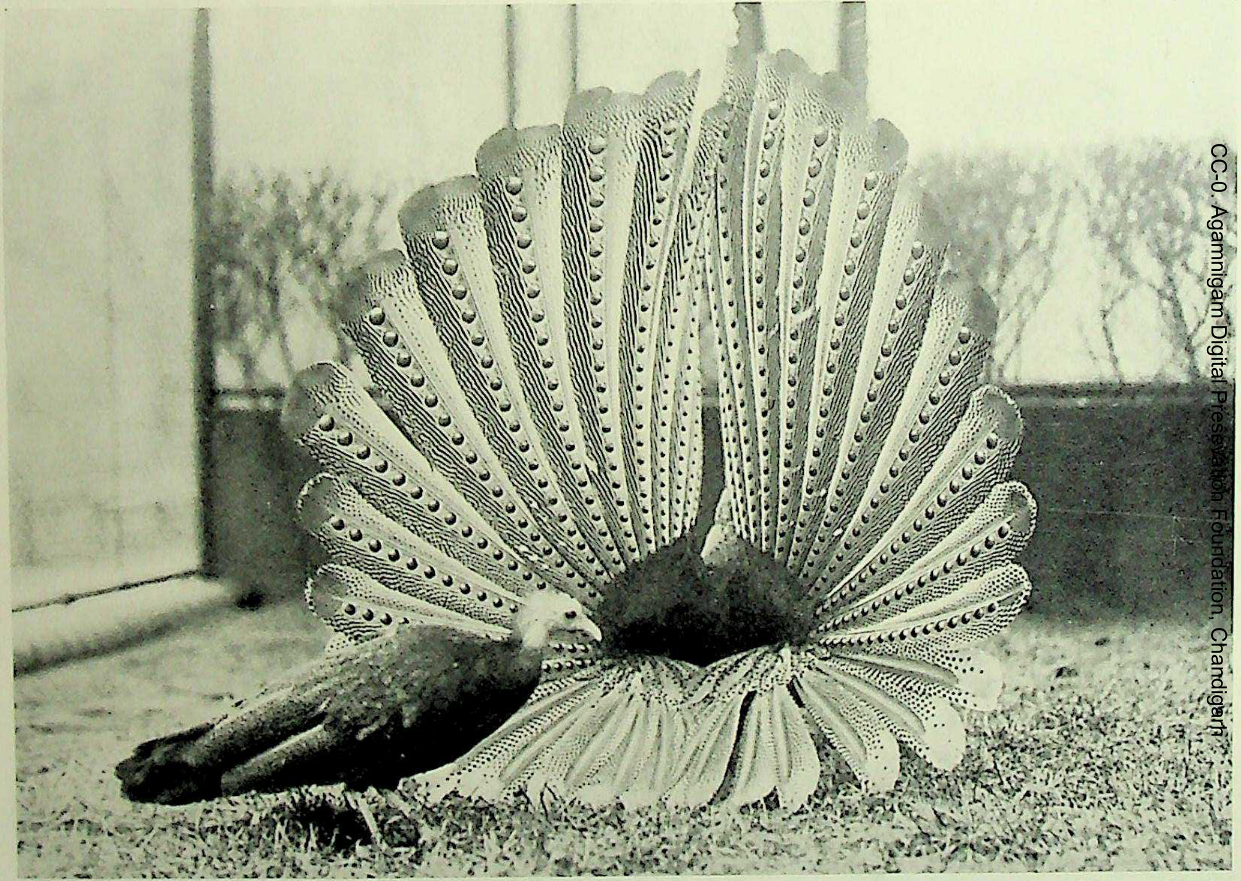
Life leaves the water completely—and grows enormous: brawn but not brain. This reconstructed creature's gesture of cocksureness is perhaps justified: dinosaurs, 'terrible lizards', flourished and proliferated for something like a hundred million years. Then they disappeared

Photo:
British Museum

This picture of a modern alligator devouring a frog illustrates rather well the idea that reptile is a superior creation to amphibian

Photo:
The Zoological
Society of London





After the arthropods the second great divergence to produce a pattern of life utterly different from our own: the birds, warm-blooded creatures of emotion and strange behaviour. There has evolved in this argus pheasant a glory of plumage that must govern his whole way of life. In the latter end his stance will no doubt set off the desired response in the female

Photo: The Zoological Society of London

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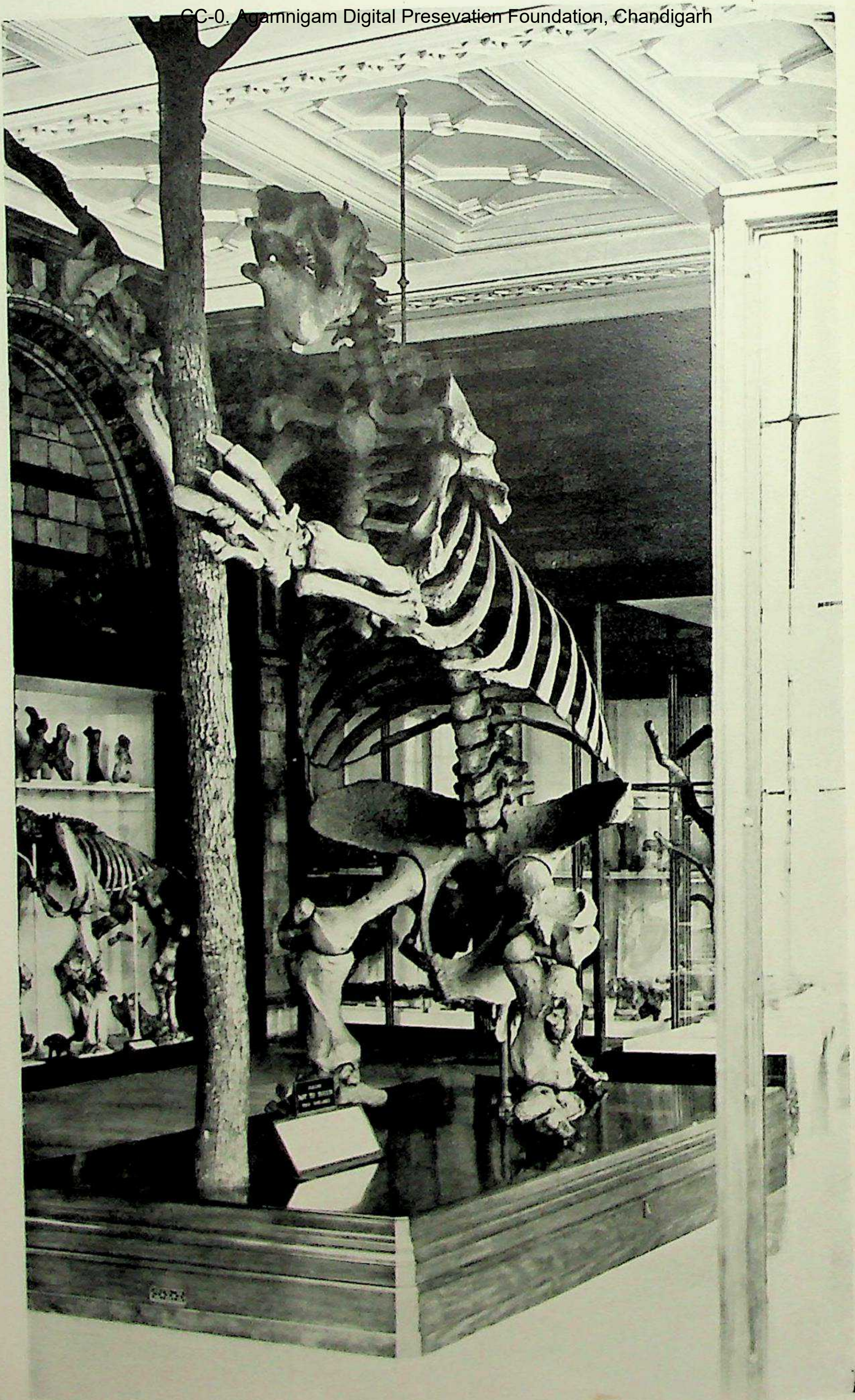

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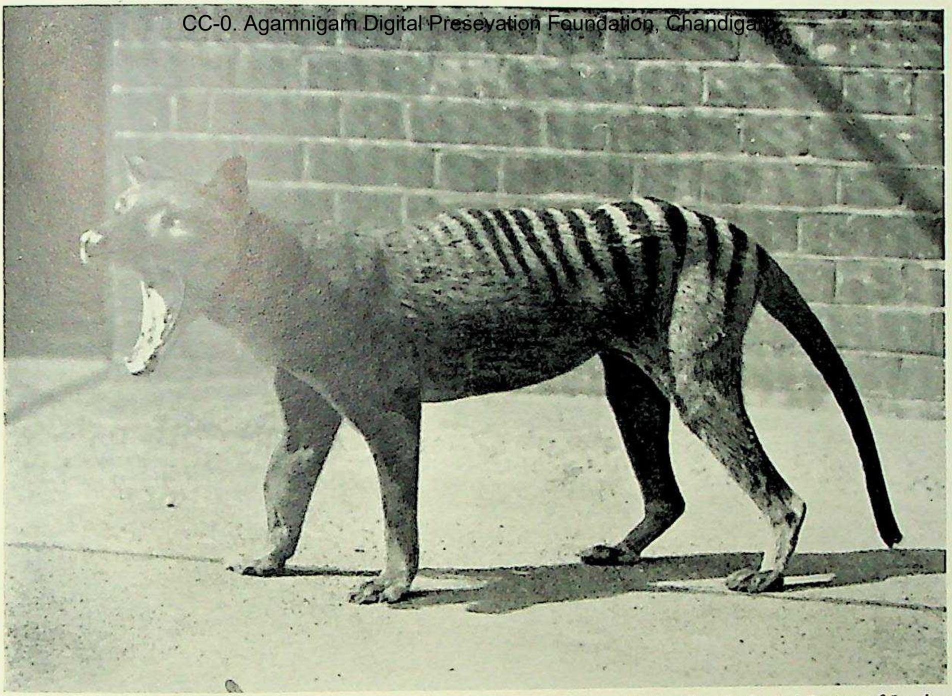


Photo : The Zoological Society of London

At length the mammals arrive—and first run to size almost as exuberantly as did the reptiles. On the opposite page is the fossil skeleton of a prehistoric giant tree sloth of South America. He squats twelve feet high

Here is a marsupial wolf from Tasmania—rapidly becoming extinct. Compared with the later breed of 'placental' mammal (to which we belong) the marsupials are unsuccessful and stupid. But compared with such as the giant sloth they are prodigies of energy, sensitivity and intelligence

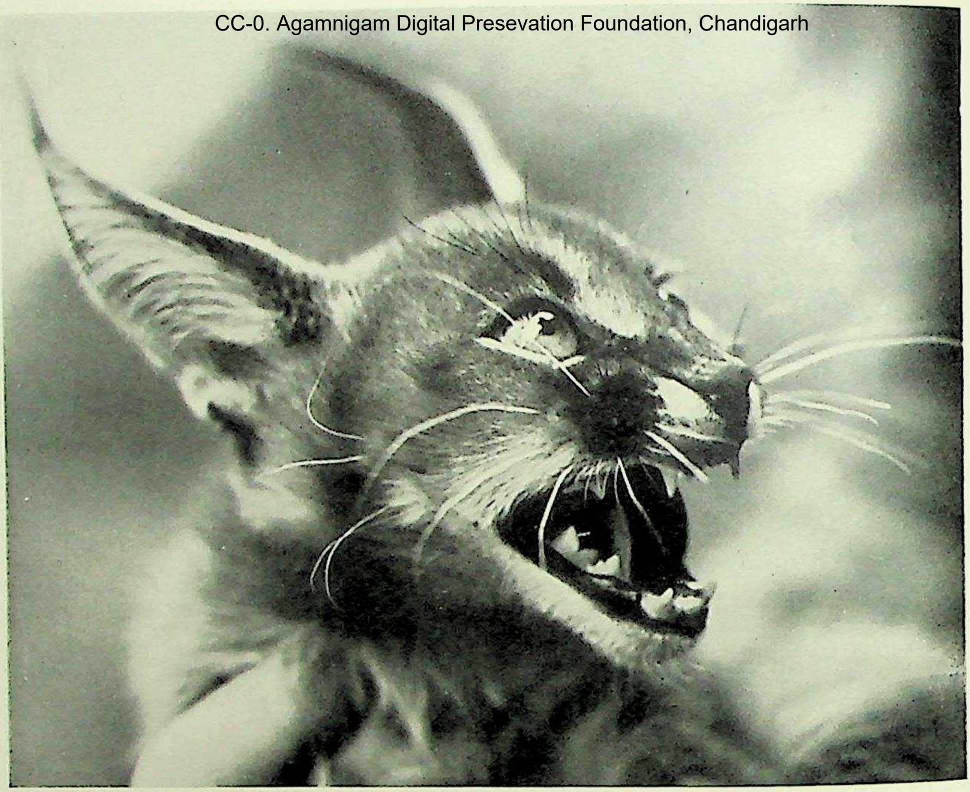
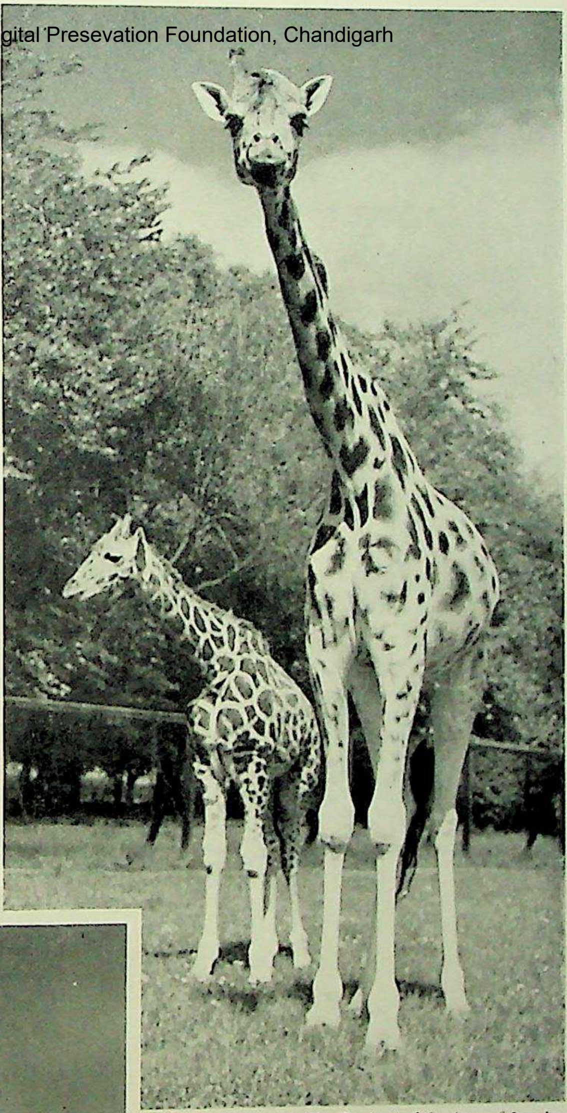


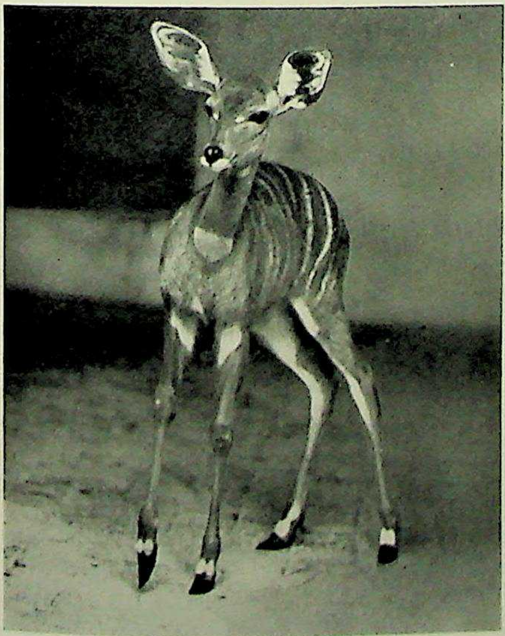
Photo : The Zoological Society of London

Specialization. This and the next four pages show some of the lines of particular adaptation along which the placental mammals chose (or happened ?) to develop. Here we have the carnivore (a Caracal, a desert or bush cat allied to the lynx). It has specialized, one might say, in ferocity

If you specialize you lose as well as gain. These ungulates, giraffe and kudu, gained fleetness of foot. But they lost the vertebrate's birthright of digits —they have no hands

The giraffe's neck has caused a wealth of evolutionary argument





Photos: The Zoological Society of London

Photo : H. E. Tyndale

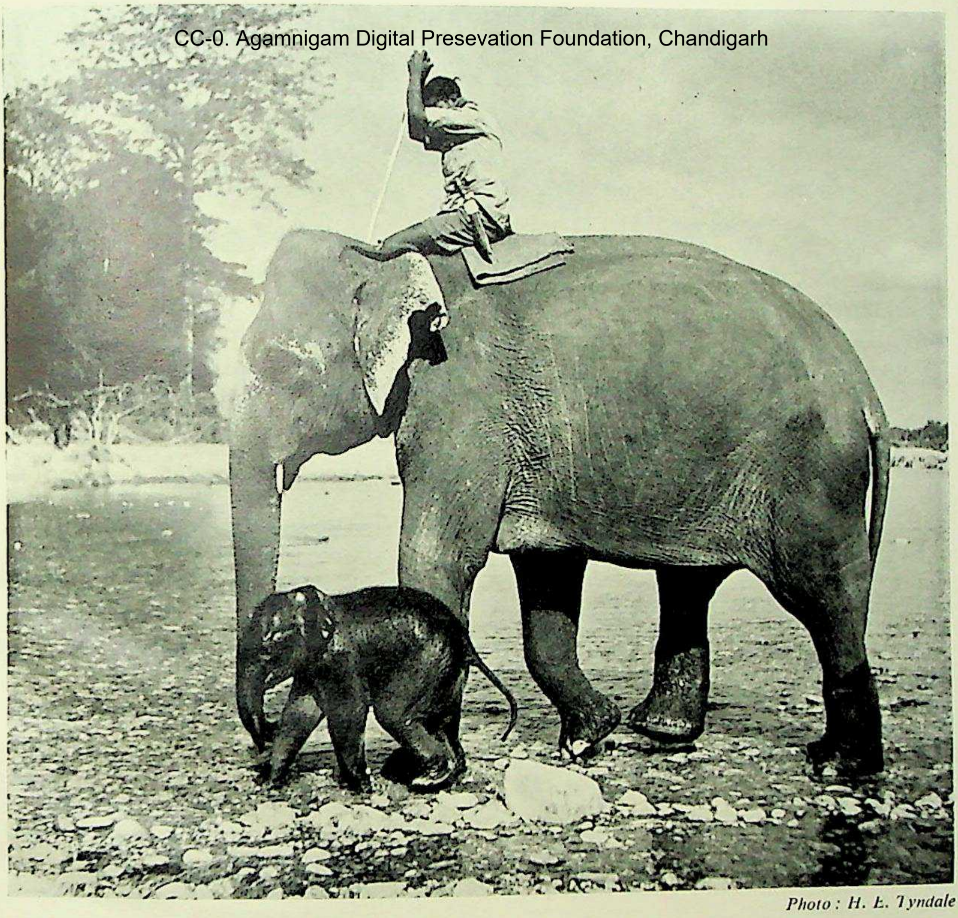


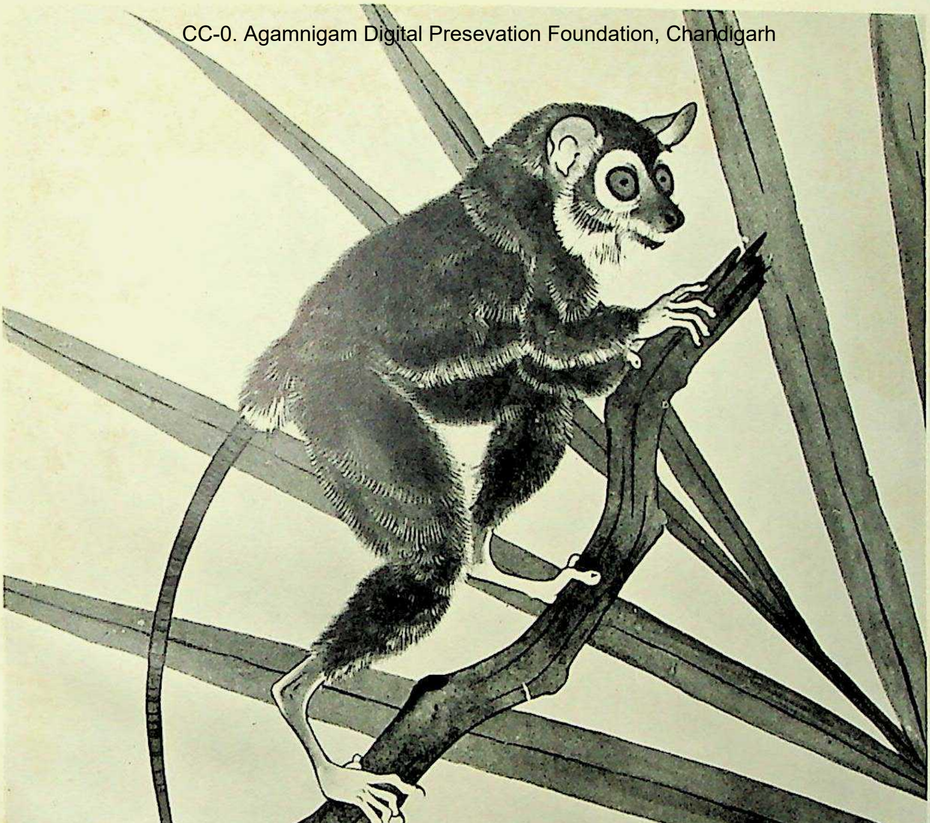
Photo: H. E. Tyndale

Rhinoceros and elephant have sacrificed both hands and lightness of foot. They have also almost gone back to the skin-armour of the giant reptiles. Rhino exemplifies the point made by Bernard Shaw about bulls: it is not only carnivores that are fierce. When he charges he is the living embodiment of momentum, weight multiplied by speed

The elephant has, as it were, created a substitute for hands out of his proboscis. This wise creature has obviously not lost the mammalian capacity for mother-love

These are two livers in trees, an English Beech Martin and a Lesser Panda from the Himalayas. They are not in the direct line to Man; but they illustrate the *liveliness* that an existence in the trees seems to bequeath

Photos: The Zoological Society of London



From a painting by Maurice Wilson for the B.B.C. Schools Publication 'How Things Began'

This is a reconstruction of an early Primate, a foretaste, a lemur-tarsier-monkey: a tree-liver again, quick of hand and eye. It ought to have existed, and if it did exist, would almost certainly be our ancestor, the ancestor of Humanity

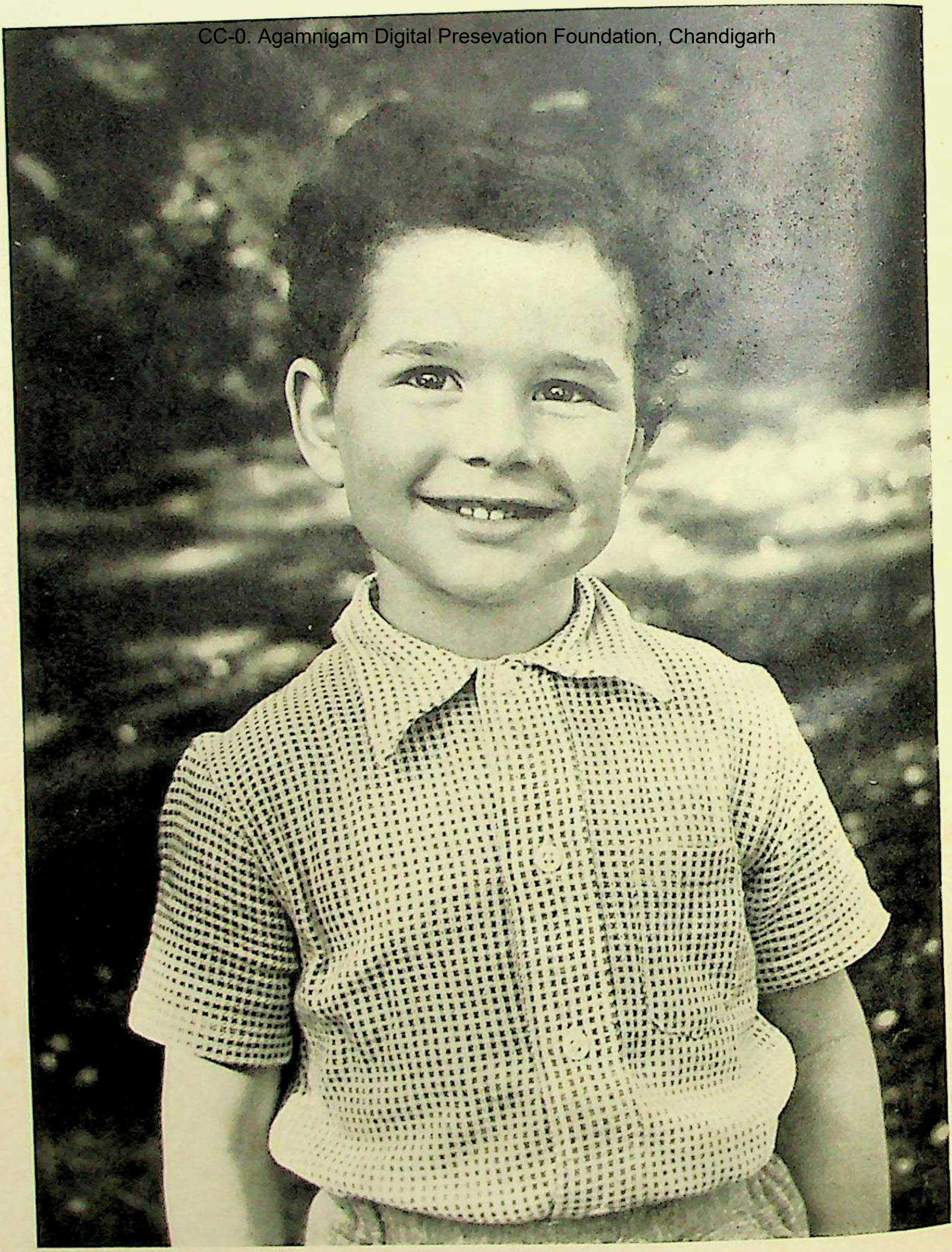


Photo: H. E. Tyndale

HUMANITY

specialized and successful of all the insects. (That the so-called white ant is not really an ant at all but a termite need not worry us for the present.)

Many kinds of ant collect seeds and store them. There is one, called the harvesting ant, that lives in the dry lands bordering the Mediterranean and collects, in particular, grass seeds. It is of it that the Book of Proverbs says:

> Go to the ant, thou sluggard, consider her ways and be wise:
> Which having no guide, overseer, or ruler,
> Provideth her meat in the summer, and gathereth her food in
> the harvest.

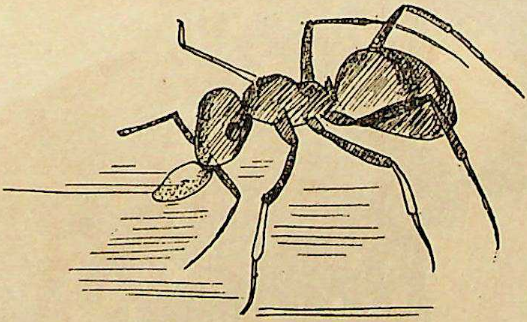


FIG. 34. Ant carrying seed

It is true that when this ant's grain grows damp it is brought out of the nest to dry in the sun. It is true too that although the seeds are usually so bitten that they do not germinate, yet if they do they are also brought out and may grow and be harvested again. But no one has proved that this is an intentional scattering of the seed for the purpose of raising a crop. Nor for that matter is it disproved.

The true agriculturists however are the leaf-cutting ants of tropical America, to be seen trooping back to their nests each carrying a piece of leaf 'like Sunday-school children carrying banners'. These carved-out pieces of leaf, having been chewed, deposited in the dark recesses of the nest and there tended, weeded and manured by the excreta of the ants, produce a special miniature toadstool-like fungus which is the food of these ants. Forethought even goes further than mere gardening. When the queen leaves on her nuptial flight a pellet of fungus and leaf-debris is taken with her; then when the nest is to be formed the pellet is most carefully manured afresh.

Pastoralism also is a product of the insects' unsqueamishness; more specifically it has arisen from the ants' passion for the licking up of unconsidered saliva. This time it is not their own kind's sweet dribble that is lapped but the secretion of plant lice, root aphides, mealy bugs and the like. A caress from the ant's feelers—a very skilled caress, as painstakingly imitative naturalists have discovered—and the miniature cow produces milk.

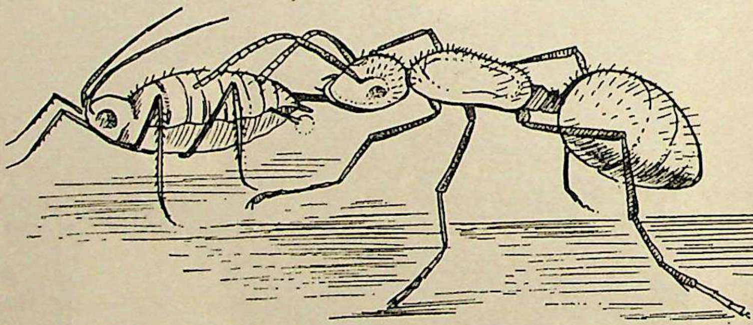


FIG. 35. Dairy farming

Obviously the analogy with human dairy farming must not be pushed too far. Nevertheless the aphides are herded and protected and sometimes actually sheltered in a rudimentary equivalent of a barn.

Further than that, in one species of ant this sticky 'honeydew' is actually stored, and stored in a most extraordinary way. The storage bins are the actual bodies of the ants themselves. The particular workers destined to become live barrels are given so much of the liquid food before their outside skeletons have hardened that their crops distend. They are pumped so full that they are capable of nothing but being suspended upside-down and of not even being able to re-hook themselves should they fall. In that state and that position they apparently live for months—waiting always for that skilled caress that turns on the tap. One wonders whether the drink measured out by these 'repletes', as the naturalist so graphically calls them, is as inexorably accurate as the nip of gin or whiskey extracted by the barmaid from the upturned bottles in the bar.

What does the 'replete' think of as it hangs for months as a live inverted decanter? Or, a more pertinent question, is the first a sensible question at all? Does the insect experience any pleasure in doling out some of its store, does it suffer any pain in being re-distended? Such questions, whether or not they are answerable, give some measure of the chasm of difference between mammal and insect.

They bring us to the third social need, that of learning to *co-operate.* For that is largely how insects have achieved co-operation: by differentiation in physical form—that, and the acquiring of a more and more elaborate pattern of instinctive behaviour.

We spoke of Man needing to acquire a conscience before he could achieve civilization. Another way to put it is that he needs to accept restraints and to exercise altruism.

Now no creature that eats its mate or paralyses the young of a fellow species so that it may be turned into a living larder can easily be called altruistic. Yet the mantis or the beetle that performs the first of these operations is no doubt suffering the pangs of hunger as well as love, and she will need to keep her strength up for the sake of her unborn young; and those wasps of the solitary kind who specialize in the second practice have very definitely the welfare of their children in view: even that bee-hunter who sucks dry her prey of honey, though she may enjoy the meal, is primarily concerned in making the corpse safe for young stomachs. There *is* an altruism then, a loving care for the future of the race—a very one-sided altruism and a very fierce one.

That is the altruism that Nature has worked upon. The first step is seen clearly in the difference between the solitary wasps and the social. The instinct of the female of the social species is to survive the Winter. After her marriage therefore she takes the reverse of a honeymoon and creeps away alone to find merely a place where her blood will not freeze. In the Spring she will do what her less highly developed cousins will do: find a good spot, lay her eggs, and forage. But she will not merely provide the food, seal up food and egg together and depart. She will nourish her grubs—mouth to mouth. She may concentrate on one particularly; she may eat a few of her own eggs, a curious way of keeping up her strength which seems in defiance of the elementary laws of the conservation of energy but which nevertheless seems to work. It is a race against time, the same sort of race as that which the poor of our Industrial Revolution played when with luck the children began earning in mill or mine before the strength of the mother gave out. For as we know, those grubs will turn into Neuters, aborted females with the instinct to nurse and forage and not to breed. As their numbers increase the queen—we may say she is beginning to earn that title now—will forage less and less and create new lives more and more. Soon she will become nothing but an egg-laying machine. As the Autumn approaches she will take care for posterity. She will lay infertile eggs that will turn into males.

So too will her workers provide for posterity: with no feeling of jealousy—for they are made that way—they will set about the creation of what they can never be, fully developed females, virgin queens. Then in due course on the right sunny day and with remarkable unanimity, the nests of the neighbourhood—and this goes for ant and bee as well as wasp—will send out their young queens for their nuptial flight, to mingle with the following males in the air, to take the risk of engulfment by avaricious and opportunist birds, to accept the terrific fertilization that will kill the male, and to sink to earth once more, and so to start the cycle all over again. The old nest—the wasp's nest that is—will gradually die with all its inhabitants as the grip of the Winter tightens and grows.

Not so, as we are all aware, the nests of the ants and the honey bees. They have progressed further; their nests and hives will survive many Winters, some potentially immortal.

The queen of honey bees will herself survive many Winters. But she is a long way from immortality—a creature that lays between one and two thousand eggs a day is hardly likely to be immortal. She will however do more than produce a brood of offsprings; she will be primarily responsible for producing a new colony. Increase in family now becomes increase of families: the bees swarm. They leave the hive, not usually, as one would expect, to follow a new queen but to follow the old. Those left behind serve 'royal jelly'—the food actually of all grubs for the first two days only—to a number of destined queens; and of these one will win a very grim race to maturity whilst the rest will be mercilessly destroyed. Finally the old queen (in the new hive) will begin to lose her powers of egg-laying.

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Again queens are reared, fewer in these circumstances; one individual again beats her rivals in the race and becomes the new ruler and the new egg-layer. And now for once there is mercy, or at least economy: the old queen is as a rule allowed to live so long as her own powers to reproduce have not wholly ceased.

So much for the queens of wasps and bees. With ants the story is very much the same—yet with a sort of exaggeration, what seems to us a hysterical exaggeration. On the nuptial flight, the queen will have not one self-immolating husband but several. Then after the flight she will tear off her wings—not masochism, one must believe, but again mere economy: the unwanted wing muscles, slowly degenerating, will help to nourish the mother and so furnish forth the feasts that she provides for her firstborn. Then the queen becomes even more of an egg-laying machine and may continue in the work, seasonally that is to say, for as long as fifteen years.

But what of the rank and file of these insects, and the variety of form that helps them to co-operate? The queen of course has that difference in form outstandingly. Even in that dark, treacly, sluggish stream, like water going uphill, that is the swarm entering the new hive, the anxious eyes of the bee-keeper will be able without great difficulty to spot the queen. In one species of ant the queen weighs a thousand times as much as her workers, some of whom, by mistake or design is not evident, get taken up on the nuptial flight, hanging on to her brobdingnagian legs. As for the queen termite, she becomes one great flaccid, immobile, tubular body, with head, legs and thorax sticking out of the front as might appear a small house fly emerging from a sausage. The queen's labour is paramount and completely distinctive.

But the rest do have their divisions of labour and their allotted jobs, in particular since, as the Book of Proverbs says, they have 'no guide, overseer, or ruler', or at least no obvious ones.

In the beehive there are only two kinds besides the queen, the male drones and the infertile female workers. So important is fertilization and the continuance of the species that like specialists in a modern army the drones are 'on the strength' and supported by the rest for the value of their one contribution. Their tongues are lazy and useless tongues, able only to reach the stored honey in the combs; only their eyes are good, able to distinguish the nuptial flight. And as is well known those who survive that flight await a bitter fate: they are not worth being kept alive throughout the Winter.

As for the worker bee, it has been discovered that her duties vary with her age—which means in practice that they vary with her physical condition. Out of her forty or so days of life the second twenty will be spent as a forager. Her job for the first three days will be domestic, keeping the brood cells clean. She will then start feeding the elder grubs and on the sixth day transfer to the younger grubs and queen grubs, for then she has become capable of secreting the royal jelly. For six days she has that important task; then she is relegated to wax secreting and comb building; and from then on as her last job before she is honey-gatherer, she guards the entrance to the hive.

The ant once again seems to go to extremes. There is another caste beside the worker, the soldier. He is big and he is armed—armed in the same way as a lobster is supplied with tools, that is to say by an adaptation of his physical make-up. His jaws become a lance. This has one inevitable result: he cannot feed himself. In one kind of ant the head also becomes conveniently flattened and when a nest is pierced these soldiers not only guard the door but for the time being *are* the door, a tight shut door. It is the same complete sacrifice of individuality as of the honey-pot ants.

The social insects in fact *co-operate* by obeying the law that Christians are exhorted to follow, of walking contented in that way of life into which it has pleased God to call them. But the way is made easy for them because their instincts and in particular their physical form leave them neither desire nor ability to do anything else. They do what they are created to do. . . .

Yet, you may well say, that grand generalization does not explain how in detail the social insects manage to co-operate in the day-to-day, minute-to-minute running of their homes; particularly it does not explain how the last of the four necessities for social success is achieved, the meeting of emergencies.

Yet they do cope, they do meet emergencies. The honest answer to the question of how do they do it, is that we do not yet know. We do not understand very much how they communicate with one another, how they become aware of a changed situation. Insects' hearing is not well developed; though they may stridulate with their limbs, that is not a method that seems to afford them any great

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repertoire, emotional or minatory, and they have no vocal chords: the insect sergeant-major does not exist. There is the romantic theory of the Trumpeter Bee, who at the entrance to its nest greets the morn with a Reveille sounded with the buzz of its wings. But the more prosaic but likely explanation is that it is helping to form a draught through the hive. And that task is done by most wasps and bees whenever the hive is foul, or too wet, or too hot: an intelligent response to an emergency that however does not need much or anything in the way of communication.

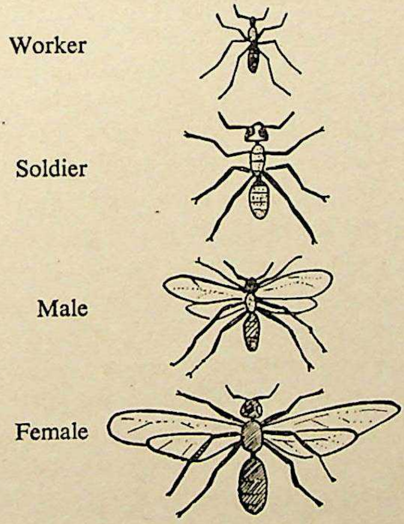

FIG. 36. Ants

There remain as possible means of passing on information the senses of smell, sight and touch.

Insects' powers of smell are miraculous. Fabre, after experimenting with the amazing faculty of the Emperor moth to search out his mate, suggests some power at which we can only guess, some awareness not so much of a smell as of the ghost, the emanation, the vibration of a smell. Modern scientists would hardly countenance that, though they have no alternative explanation to offer. A smell to a bee or ant is undoubtedly as emotionally stimulating as a forest of flags to a Xenophobe. Theirs is a smell patriotism. If a fellow worker or a queen has your nest smell, all is well; if not, repulse her, eject her, kill her!

Sight cannot always be effective because inside many kinds of nest it will be dark, and for that matter some worker ants have no eyes at all. But when there is light with which to see and be seen, then the dumb will always gesticulate—and those tell-tale dances of the bees cannot surely be the only examples among the social insects of the passing of information by means of significant movements.

Perhaps touch is the most effective. The social insects are great exchangers of food from mouth to mouth. 'One would never tire', says Fabre of wasps, 'of the curious spectacle of these rough soldiers playing the part of tender nurses', and goes on to describe the grub being wakened by a gentle nudging feeler before being gently fed. Ants are always soliciting food from one another, or else persuading their plant-lice cattle to allow themselves to be milked, and many observers have commented on the strangely caressing method of their approach. Stroking evidently means a great deal to a social insect.

And yet there is obviously much unexplained. What sets the driver ants of the tropics on to one of their terrible and highly organized advances that engulf anything edible which gets in its way, even up to the size of a pig? Hunger, presumably. But what sets off the trigger? Perhaps the only useful analogy is the crowd mentality, the queer way in which a human crowd seems to change, to override the mentality of its individual members and to develop an unpredictable and rather sinister one of its own—so that suddenly and inexplicably something happens. The legionary ants have become so specialized as a race of soldiers and so degenerate that they have to enslave other races of ants to work for them and feed them. Here too the sudden organizing and setting out upon a raid seems to us unpredictable. But there does, we are told, appear a rhythm about this business and the raid seems to be worked up to by a feverish laying of eggs by the queen and the rearing of a mass of new conscripts.

In fact, *circumstance* in the nest seems to govern behaviour. That is in a way particularly true of the termites, of which we have said little. The parallelism of their evolution with that of ants is very remarkable. But each of the two species of insect is so different that one, the ant, goes through the full metamorphosis of grub, cocoon and imago, while the other, the termite, hatches in the more primitive manner into what is very much a small edition of the final product.

And yet termites too have soldiers and workers, sexual and neuter

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castes. All this does not come about in the same way as with the ants however, with infertile and fertile eggs and the special feeding of the latter. There are neuter males as well as neuter females, and there may appear at times what are called 'substitute sex forms' that can for a while lay eggs and fill the role of queen. This is all rather complicated; but the point is that whatever kinds shall be produced, or rather whatever kinds the embryo creatures after hatching shall grow into, seems to depend very clearly upon the condition of the nest, on *what is wanted at the moment*. A balance in fact is maintained—though how it is maintained nobody knows. It is as if the nest had an entity and a power of its own.

Now that is a very rash thing to say. Yet, having considered the four necessities of an insect society, it is an idea to which one finds oneself continually being led. Another way of putting it, perhaps a more helpful way, is to say that the hive or nest lives only while the queen lives. The queen's influence with all these insects is quite incomprehensible but all-pervading. A nest without a queen is unthinkable; a nest in which the queen has died becomes chaotic, dispirited, moribund. The queen is like the heart to a body.

Indeed that is the final analogy, a dangerous one but fascinating. The nest is like our body; and the insects in it are like the cells of our body or the corpuscles of our own blood, separate specks of life yet obeying a higher control to produce a higher, more complicated entity.

If that were so then the single insect would have no individuality at all. It is not wholly so. But there is a likeness, there *is* a degree of sameness. And Nature in the way she acts does not discourage us in making the comparison. It is the nest that matters, the community; never the individual. All the elaborate instincts are implanted to that end. When the drone is not wanted it is thrown out; even when towards the end of the season the grubs are not wanted, those very nurses, a moment ago so tender and solicitous, will become rabid murderesses, merciless hygienists, who tear out and throw away what have apparently changed from pampered heirs to dangerous rubbish.

It is a ruthless, hit-or-miss and unintelligent principle. Let us end on that note, lest we become too impressed with the ordered marvels of insect life and depressed at contemplation of our own inadequacy. It is legitimate to do so. Fabre extracted a wasps' nest and put a glass dome over it. Those returning, from the light to the expected darkness, had the instinct to burrow a little through the earth and so get home beneath the dome; but not so those coming out, who flew up to the glass roof, and fell back, and went on falling back until they died. Another wasp, deprived of normal sources of food wherewith to feed her grub, excelled herself by biting off the grub's rear and presenting it as food to the front. Even that rather endearing habit of stroking and exchanging food can lead the insect astray. The homes of the social insects are full of parasites that take advantage of this offering of, or liking for, sweet excreted food. There is in particular one largish beetle that is tolerated in the ants' nest for what it has to offer in this way. But its own food is the larva of the ants themselves. It is, say the authors of *The Science of Life*, as if we welcomed to our homes 'monstrous animals which we allowed to eat our babies in their cots because they secreted hot rum-punch or some equally fascinating liquid'.

Nevertheless the nests survive and perpetuate from year to year and decade to decade. The wasp and the bee thrive whether social or solitary. The insect, as we said at the beginning of this chapter, succeeds.

He does it by means of instinct; instinct is the talisman, the tool, of his success. His brain is small because he himself is small—*that* is the ultimate significance of the insect's necessary smallness of which we spoke at the beginning of these two chapters. Indeed his brain by our standards is hardly a brain at all. Reasoning power was for the insect apparently an impossibility; but instinct was an adequate substitute.

And instinct is a sort of *superimposed pattern*, a pattern in time. We shall come back to that idea in considering the evolution of birds.

CHAPTER XI

Blithe Spirits

OF 'the handsome and loquacious whistling widgeon', W. H. Hudson, in his unemotional and urbane manner, speaks as follows:

> 'The handsome and loquacious whistling widgeon of La Plata . . . has a pretty aerial performance. A dozen or twenty birds rise up until they appear like small specks in the sky, and sometimes disappear from sight altogether; and at that great altitude they continue hovering in one spot, often for an hour or longer, alternately closing and separating; the fine, bright, whistling notes and flourishes of the male curiously harmonising with the grave, measured notes of the female; and every time they close they slap each other on the wings so smartly that the sound can be distinctly heard, like applauding hand-claps, even after the birds have ceased to be visible.'

Julian Huxley tells us of the courtship of that quite ordinary bird of the seashore, the redshank, and describes the cock bird advancing on the hen with his graceful pointed wings raised above his back, sometimes fluttering so that for an instant he walks on air and all the while uttering 'a clear far-carrying trill, full of wildness, charged with desire, piercing and exciting.'

Miss Len Howard, who entertains great tits in her cottage as other people entertain people, speaks of her birds' 'courage' and 'nervous habits', of the expressions on their faces and their observance of her expression, of grown-up tits sliding on her pillow for fun and of babies 'playing at kissing'.

What kind of life, then, have we come to now? As graceful, as emotional, as passionate, as sensitive and intelligent as our own at its best? But wait! There is the oft-told—and annually re-enacted—story of the young cuckoo, who kicks out the other nestlings and continues to be fed by her fond and idiotic foster-parents at the expense of their own children which may even be gasping their life out only a few inches away. Bird life in some aspects is as alien and incomprehensible to us as is the life of insects. In others it is as responsive to our understanding as it is delightful.

We need to know how it all happened. The evolution of birds runs concurrently in time with the evolution of the other great and successful division of the vertebrates, the mammals. Both, it is believed, evolved from the reptiles.

That such a quick and hot-blooded and emotional creature as the bird should have evolved from a reptile is surprising—though in the suddenness of their movements and their intervening stillness there is in the birds a reminiscence and a suggestion of their likely forbears. Something much more definite in the way of evidence does exist however: two fossils remarkably well preserved in the fine-grained Jurassic rocks of Bavaria. These were called Archaeopteryx and Archaeornis respectively, and as one means 'ancient-winged' and the other 'ancient bird' there is not much to choose between them—the first discoverer, impressed by its queerness, not to say monstrosity, wanted for that matter to call it Gryphosaurus or gryffon-reptile. This creature had the pointed teeth of a reptile, the fore-claws of a reptile, the tail of a reptile, the heavier bones of a reptile, but the wings and feathers of a bird. It was about the size of a crow and, as somebody has said, it must have looked 'like a lizard dressed up in feathers'. Its most curious feature was its long feathered tail so unlike the short rump of a modern bird with its fan of feathers that are used so successfully as a brake and control on landing. Archaeopterix must have been a very clumsy flyer. In the rocks of the next Period, the Cretaceous, has been discovered Hesperornis, a diving bird essentially similar to the modern bird in wings and tail, but still with pointed reptilian teeth.

But the acquisition of *feathers*, that is the great step—as it is also however the least satisfactorily explained. The accepted explanation is that the reptiles' scales 'split' and became feathers. Perhaps reptiles had on the other hand to lose their scales before there grew either feathers or hair. It is a fact, however, that birds remain with scales on their legs.

Feathers are a marvellous retainer of bodily heat. They are also, obviously, a better potential mechanism for flying, more efficient for speed than the stretched membrane of the pterodactyl or the bat. That raises the interesting question as to which came first, feathers or flight. Some think it more likely that flight came first—flight of a sort, that is to say, with a stretched membrane—if only because flight itself is a draughty business and would make a feather covering highly desirable (or in Darwinian language 'of survival value'). There are others who think the reverse and even hold that the world's flightless birds, of which there are and have been many, are not creatures whose wings have atrophied but are, as it were, a more orthodox descendant of the original bird. Perhaps the most probable truth is that there was not one original father of the birds but several, archaeopteryx being not one of those 'whose seed shall cover the earth' but rather an unsuccessful and freakish experiment.

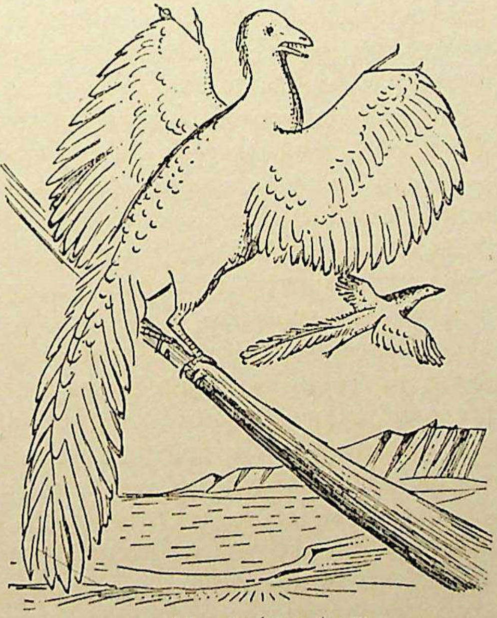

FIG. 37. Archaeopteryx

What is important to realize is that birds did *not* evolve from the flying reptiles. Those beasts, all wings and no free limbs, had, for all their exuberant variety, travelled up a blind alley, or at least an alley that, without the boon of warm blood and a covering of fur or feathers, they were unable to exploit. They were before their time, they were impatient and missed a necessary step—and they were scrapped. Of the flying reptiles all that is left to remind us is a few species of minor, volplaning lizards disporting themselves harmlessly in the high trees of what is left of the tropical jungles.

Birds achieved complete mastery of the air, and to do it they had to make quite drastic changes in their bodily pattern—which, with their new way of life in the wider element, led on to changes in mind and character that are the more significant of the two.

First the body.

The prerequisite for the sustained effort that proper flight entails is an efficient heart. The bird has that, a four-chambered heart such as our own that can pump arterial blood round the body. Among the reptiles only the crocodile tribe has a four-chambered heart and even then uses it in a different way. Then must come good lungs to oxygenate the blood that the heart is pumping. One can easily imagine that were we able to fly—the 80 or 90 miles an hour of a swift or even the 30 or 40 of most of the smaller birds—we should at the very least get out of breath. The bird does not do so, at least not in the way of finding it difficult to draw enough breath into its lungs. For when it has forced the used breath out—and the very action of flying helps—fresh air comes in automatically from air sacs distributed about the body.

The bird's bones too are filled with air and not with marrow; muscles used on land have atrophied, as has the long heavy tail of the reptile—archaeopteryx was perhaps embodying an unsuccessful attempt to use it as a rudder—the breastbone has changed to a keel on to which are attached fore-limb muscles hardly comparable to ours (Daedalus must have got very tired). In fact the aero-engineer is not the first designer who has exercised ruthlessness and ingenuity in adapting structure and reducing weight. The bird's beak is a miracle of lightness—were it not so such birds as the toucan or hornbill could not exist—and a miracle of strength as well, being in another way from the elephant's trunk a substitute for hands. Finally the bird possesses a digestive system which makes remarkably complete use of its food, providing itself with a powerful muscle-grinding machine, into which the seed-eaters introduce grit and stones as an additional substitute for teeth—a sort of internal tool.

Now what does all this amount to? A mechanically efficient animal; life tackling its environment, physically adapting itself to it, gaining control over it, and all with great success. That is a great thing. But trilobite did something of that, fish did something of that, arthropod, amphibian, reptile. By now in the history of evolution we may expect something more, something less materially significant but more mentally and spiritually so—there is no reason why we should not mention that last attribute in talking of the higher animals. In mammals we get it, in man we certainly get it. Nor in birds shall we be disappointed. Not in the least.

It begins it seems with the bird's temperature. No one can say with certainty why the bird should have such a high normal temperature. Perhaps, if it evolved from some small running lizard, as it may well have done—the present frilled lizard, that has learnt to raise its front legs off the ground, runs remarkably like a chicken about to fly—perhaps, if it started from some such small quick creature it started too with a high temperature. It is as if the bird took over from the reptile at the exciting heat of noontide and then by means of its efficient covering of feathers managed to remain in that state. What is certain is that modern birds run a normal temperature of up to ten degrees Fahrenheit higher than we do ourselves—and that is really an extraordinarily great difference.

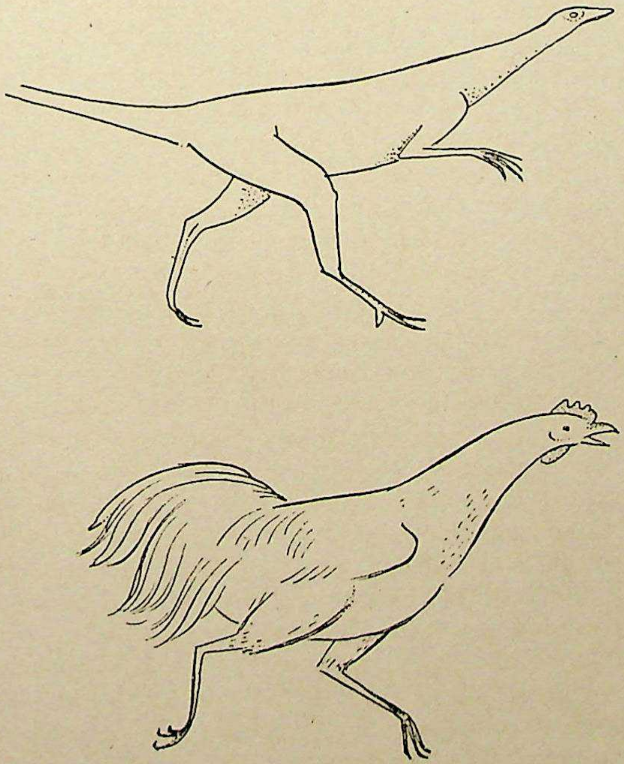

FIG. 38. A similarity of motion

It means that the bird lives in all respects at a much higher rate, that their metabolism, their bodily processes and nervous reactions, must be altogether speedier. How much that means is not easy to imagine. H. G. Wells once wrote a short story called *The New Accelerator* that in an exaggerated sort of way perhaps gives an idea. A marvellous drug makes the fictitious inventor and his friend live a thousand times as fast. They dash about the Leas of Folkestone so rapidly as to be invisible while all life about them seems almost stationary. A bee flaps its wings at the speed 'of an exceptionally languid snail'; a man winks at a girl, and to the two intensive onlookers its leisurely deliberation is an unattractive thing—it loses, says Wells drily, 'its quality of alert gaiety'. So in a lesser degree may humans seem painfully slow to birds.

But there is of course more to it than that. No one can really appreciate what it is like to be a bird, though the more we know the more we begin to realize that it is something very strange and different. One word probably sums it up better than any: a bird undoubtedly lives with *intensity*. It is not for nothing that our word 'volatile' derives from the word for wing. The bird one might say is Life's experiment in living on the emotions.

And again: not only that. The creature's emotions—so the last fifty years of enthusiastic bird-watching have taught—are curious and curiously evoked. Its brain and its behaviour are as different from those of any other of the higher forms of life as is conceivable. Sophocles called birds 'frivolous minded'; Julian Huxley has said of them—more politely and quoting from a Frenchman who was actually talking about something else—'ils n'ont que l'ames', they have not minds but only souls. Sir Charles Sherrington—whose great book, *Man on His Nature*, is as thought-provoking as it is difficult—has slyly thrown out the idea that the future of the world might lie with a race blessed by the possession of a bird's brain matched to a human cortex. Undoubtedly birds intrigue mankind. . . .

CHAPTER XII

A Bird's Life

IF we set down, more or less baldly and without comment, the things that happen to a bird and that a bird does throughout its life, we can perhaps come back the more successfully to consider the creature's mind and behaviour and the evolutionary significance of these.

It is a little difficult to find a representative bird. Nevertheless the need to support themselves in the air sets a certain conformity upon the birds' bodily plan (and certainly a limit upon their size), so that they vary within much narrower limits than the mammal. This of course excepts the flightless birds ; but, whether these are evolutionarily a retrogression or a virtual non-starter, it is I think true that they largely display only the more foolish side of the avian character —quite a few of them have become extinct—and that they are certainly not representative.

Let us then take for our archetype a *passerine* bird—which should by derivation mean sparrow-like but in fact means a perching bird and so to most of us just an ordinary bird. We will conveniently refrain from narrowing it down to any single species.

Our bird on first seeing the light will have caused no birth-pangs to its mother, but it will have struggled as purposefully as any mammal to come into the world—it may even have evolved a special small weapon on its beak for the sole purpose of breaking the shell of its egg. It will find itself in as warm and comfortable a situation as any marsupial babe and without the necessity of that hazardous journey into the mother's pouch; and it will have need of this protection for it is just about as immature. For the first few days it will not even have the power to keep its own body heat above the temperature of its surroundings. It is no more than a featherless bag of skin and bone attached to an enormous gullet and beak.

That beak opens when a shadow passes over the nest and follows the shadow as it moves. If the nestling is lucky the shadow will be its mother or its father bringing it food, protein food that it can digest. The gaping beak will be brightly coloured, which is a useful guide and signal to the parents. The appetite of the body behind that beak will be, as anyone knows, phenomenal.

Soon the nestling will be able to see. It will see its parents and form a great attachment to what it sees. From other looming shadows it will instinctively cower into the nest—if it does not do so its mother's warning voice will teach it. If it survives the bird of prey and other dangers and vicissitudes it will grow in strength and perfection of feathered wing, but will be loth to leave the nest.

The parents encourage it to fly, not teach it but encourage it. Immediately it has taken the first plunge it can fly, though naturally not yet with skill or versatility. It will still need to be fed. It will venture on to the ground, where in spite of its mother's scoldings it will seem less on guard against the dangers of the land than of the air; it will be lucky if it survives.

At last as the Summer progresses it will learn to fend entirely for itself; if its parents are hatching another brood the break will be all the more drastic. The young bird has become one of the flock.

Then comes the first of the many turns of the wheel in its ordered cycle of living. Autumn has arrived and the days are growing shorter and the nights colder; something has to be done about it. Not all birds migrate; but even those that do nothing so spectacular will make some change in their way of living, if only a move from the hill into the sheltered valley. The great thing is that migration is a possibility: birds by taking to the air have found yet another way of surviving the hard, lean season of the Winter—by mitigating it or avoiding it altogether.

Some kinds of bird that spend the Summer in this country migrate southwards for the Winter, many as far as Africa; let us suppose that our bird is one of these. He may do something rather peculiar: he may set off with the other youngsters *before* his parents. How he knows or finds his way nobody has yet been able to discover.

And now of this wintering and ensuing winterings there is not very much of significance to tell. Our young bird will live with all the other birds of his kind, not as one of a small family but as one of a large flock. The flock will forage for itself, working the fields, the edges of woodlands, the barns and huts and habitations of men; and it will do all this amicably, sharing out its food supply. There will be times of noisy excitement: on going to roost, at dawn perhaps when some species fly up to greet the sun, and at other unpredictable times when there will be communal flights, controlled no man knows

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how, unless it be telepathically, each bird so emotionally attuned to each and all of his neighbours that it is the formation that flies and not the individual. But then when the seasons have turned and the Winter is nearing its end, significant things begin to happen. The males will begin to quarrel. It will be nothing much; the quarrelling will not be about food, indeed it is hard to say what they are quarrelling about. They flutter their wings at each other, they assume threatening gestures, neck down and head thrust forward perhaps in the so effective belligerent stance of the goose. But there seems no reason for it all; in human society one can imagine people saying, 'Willie is so *strange*, really it's as if his nature was changing!'

Willie's nature is changing; millions of birds all over the world, as their home on the planet tilts towards the heat and power of the sun, are changing. They are ceasing to be neuters; the gonads, the sex glands, are pumping hormones into their blood, and they are becoming males.

But Nature does not set her drives towards destruction, she sets them towards the increase and perpetuation of the race. Before the newly aroused strife becomes intensive the males are filled with another and stronger urge, to get away, to get apart. If the bird is a migrant, as we imagined ours to be, then he will return the way he has come, hugging the coasts in his course and taking his time where he can, losing no doubt some of his weaker companions if there are long stretches of sea to cross and the weather is bad.

Now comes the all-important business of staking out a claim for territory, more urgent than any gold prospector's since it is not merely profit that is the prize but success in the fundamental purpose of the bird's life. It is not a claiming of territory exclusive from every other sort of bird but it is from other males of his own species.

Let us come back to our own young bird, not yet a year old. He is now, nevertheless, a responsible male. He is also a lone male, for the females are slower to feel the sexual urge and remain longer with the flock. Yet there is no sign that his loneliness bears heavy upon him, indeed he appears to glory in it.

He sings. For some time now, as his quarrelsomeness grew so have grown his powers of singing. If he is one of the tribes of great songsters, he will improvise, he will embroider. But whether plain or decorated there will be a basic song of his kind, and that he will not learn; it will come to him at the right time, unlearnt—unstudied, from some fount of race memory or race instinct, one of the most immaterial, surely, of the aspects of heredity and evolution.

And all this soulfulness, this glorious surge of sound that once burst newly upon a dull and half silent world, that has gladdened the heart of men and inspired a hundred poets—all this, is it for no more than to advertise a selfish possessiveness and to frighten off a rival? I think all of us, when we first heard an affirmative answer to some such question as that, have been bitterly disappointed and disillusioned. But it is not the true answer, the question is unfairly oversimplified; we shall find the fuller answer as we proceed.

Our bird, none the less, is going to be highly selfish, highly bombastic and highly belligerent, and he is going to use his voice in the display of these attributes. He will do it from a vantage point. With his territory as yet only vaguely defined he will choose certain commanding positions, certain potential headquarters. He will fly from one to the other, pausing to sing at each. Gradually their number will be whittled down.

Other birds of the same species will be doing the same thing. Will he meet them? Undoubtedly! And—let us face it—being a newcomer to the job the youngster may fail to establish a territory altogether; or for that matter and to anticipate, he may fail, even possessing a territory, to attract and keep a female—and what bitter passing emotions that may engender, undeepened by reason or memory as they may mercifully be, we can only imagine. Birds' territories are fought out, or, more often perhaps, threatened and postured out, to a great degree of exactitude. It is all largely what we should call psychological: the bird in what he considers his own territory is the more sure of himself and hence is likely to be the victor. Like Sir Galahad his strength is as the strength of ten because his heart is pure—or at least because his conscience is clear. Indeed we might stretch the simile a little further, as a simple sum in arithmetic. Unquestionably in his own territory his strength is indeed ten —and the interloper's roughly nought. But shift farther and farther out from the centre of the one's territory and the ratio changes; somewhere the score will be five-all—and *there* the territorial boundary is.

The male birds however have no overmastering desire to fight. They prefer to perch on their headquarters, their favourite vantage points, and to 'play song tennis', as one ornithologist has put it, with their rivals and neighbours. This may not be heroic; but it is very economical in life and bloodshed, and it is aesthetically satisfying for all concerned—human beings included.

Soon now it will be the female who is concerned. In three weeks' time or so she will have arrived upon the scene. When the male sees her, he will probably do a most surprising thing. He does not seem to recognize her for what she is; his immediate reaction is to assume his threatening posture as if she were a male. She flies away.

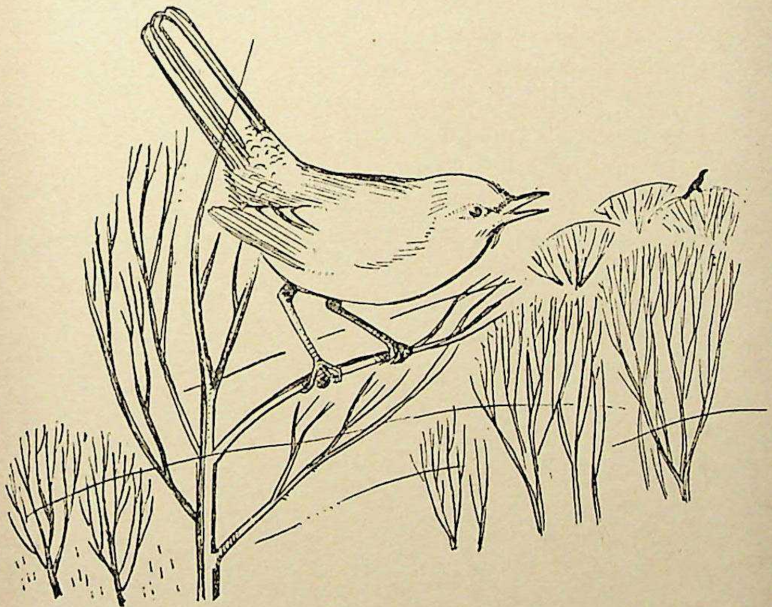


FIG. 39. A singing match

But she will come back—she or another. And this time it seems likely that she has been more genuinely attracted, from afar that is to say by the singing. For that is the second great role of birds' song, the equivalent of the female moth's lure of scent. But here there is no subtlety about it; it is a shouted advertisement, 'Here I am!' If it is not exactly a love call it is at least a call to love.

Yet in spite of that the male bird may well threaten again, it is his first automatic reaction. The female does not fly away this time. The male perceives his mistake. Not at all abashed, his threat postures give place to courtship postures—there is not always for that matter very much difference between them. The male will strut and flutter his wings, he will show all his beauty of form and colour : he will seek to excite the female. Then he will chase her in flight—and she will let him chase her, and it will become something which we, watching, would call either a ritual or a game. But as yet there is no pairing.

The female may fly off. And if she does the male will resume his impassioned singing—to stop once more when the female returns. There will be more posturing, more flight-chasing. The pair are becoming used to each other. The female will begin to help in defending the territory—against other females. But still there is no mating, however ardent the male may be. The female is not ready.

But one day she begins to take a special interest in a particular bush or piece of hedgerow. She begins to be what we should only call fidgety. She takes up in her beak a twig or other piece of nest-making material. That is the sign. The mutual exitement increases. At last the female crouches in the stance of invitation and pairing takes place.

During the next week or fortnight the nest is built. This is essentially the female's job. The cock may help, though if he does it is likely to be in only a rather desultory fashion. He may stand aside and sing. He may even make ridiculous abortive 'cock nests' of his own, as if a human husband, feeling something was expected of him and catching the prevailing atmosphere, were to try his hand at botching up a layette. Even the female may at the beginning make a few abortive efforts. Lack of practice perhaps ? We shall see.

There comes the next great excitement. A new restlessness seizes the female. She pays frequent visits to the nest. Finally in perhaps four separate visits of half an hour's duration she lays her eggs.

The female sits to hatch her eggs ; the male sings with all his might again. He finds time for this even though now he has to forage for two ; nor does he in any way neglect his mate. There may even be a certain formal courtliness with which he presents the food ; and so, too, a certain coyness and childishness—or so it would seem to us —in the way in which his partner takes it, supplicating and fluttering her wings much in the way that later her fledglings will flutter their wings at her.

Another fortnight, and the eggs are hatched. Then comes the grim and anxious time for the parents, there is little energy to spare for our cocky young cockbird to sing now. After a few days of feeding from the crop the young will need fresh food—insects, which all through the hours of daylight have to be found. Here is indeed one reason for migration away from the near-tropics to a place where the hours of summer daylight are longer. For it is, very really, a race with time: the strength of the nestlings has to be built up from nothing so that in what remains of one short season they may become fully grown.

So we are in fact back to where we started in our review of the life of a passerine bird, back to that incredibly ugly, incredibly importunate, gaping and highly coloured mouth to be fed. The parents are model parents now, both of them, quite unable to resist the appeal of the gaping mouth.

That indeed is literally and even tragically true. Birds will sometimes feed the young of other species; and there is always—the cuckoo. In fact it will be well, and relevant for the next chapter, if we end with a short account of that very sad and to our way of thinking so very unnecessary drama. The chances are, fortunately, against it happening to our chosen young bird; but the possibility is there, if the cuckoo's egg is laid in his nest what will happen is a certainty.

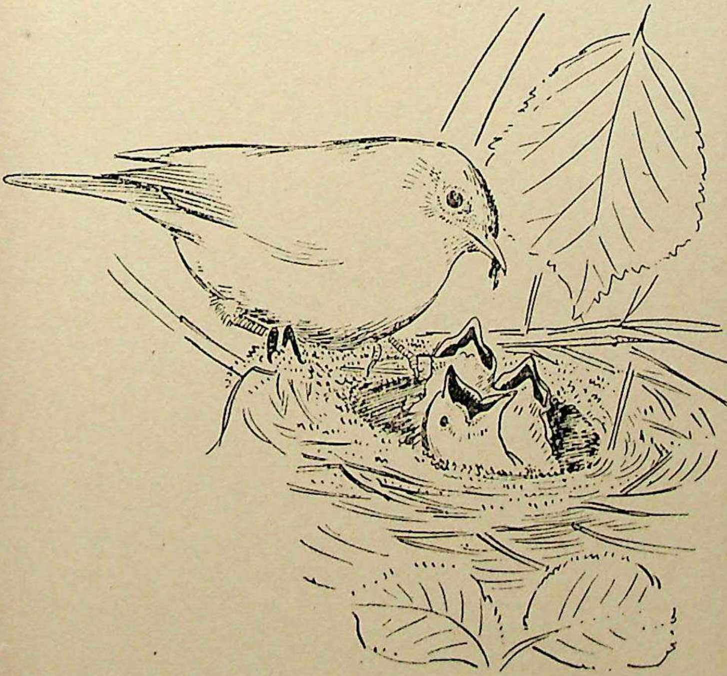


FIG. 40. The gaping mouths are to be fed

It was once believed that the cuckoo possessed the uncanny power of laying an egg of the exact appearance of those of her intended victim. What is more likely is that chance governs, within limits, the colour of her egg, and she may then perhaps do some judicious matching in her choice. But even that is doubtful : such care seems hardly to be needed.

For eggs are there in the nest to be sat upon and hatched, and hatched they will be. Then gaping mouths are to be fed, whatever their exact size and shape, and fed they will be. Soon, by a pure reflex action, the rightful young of the nest do no more than, one might say, irritate and tickle the interloper. Its reaction is automatic and its strength is superior. There is only one inevitable result, a nest housing one fat cuckoo and the true offsprings of the unfortunate pair dead on the ground below or gasping out their lives upon the leafage round about.

Yet still is there only one duty that the parents will observe. It is : *feed the mouth-in-the-nest.*

CHAPTER XIII

Pattern in Time

IT would be very wrong to let the last chapter and in particular its ending persuade us that birds have evolved to become the most foolish of creatures, that the empty air which is their element had as it were created a corresponding emptiness in their heads. Rather, they are occasionally tragic victims of their own way of life. Nature is not above working on the hit-or-miss principle; the saving grace being that the process of evolution is largely a matter of hitting the mark more, and missing it less, frequently.

Now we may look at bird life more generally. Our young passerine—hedge-sparrow, robin, bunting, tit, warbler, imagine him what you will—must be left to live out his days, of recurring passion and beauty, of hard work or mere neutral winter existence, until old age or one of the many perils that beset him ends his life and, not we are assured unknown to his Creator, he falls back to the earth from which he came. We must now widen the view and try to encompass the birds we have so far ignored, the hosts of birds that find their food in the rivers and the shallows and the seas, the birds big and little that make their nests upon the ground, the birds of prey, and all those exotic and highly coloured creatures from foolish looking toucans and haughty birds of paradise to the living iridescent jewels weighing hardly more than insects, that we know as the sun birds and humming birds. All of these have much the same cycle of existence as the passerines and fundamentally much the same way of living it out. Many however do it in a considerably more spectacular fashion.

The first thing to notice is that most of these other birds do not possess the territory-holding habit to such a marked degree. We need therefore to ask, what is the real purpose of holding territory, and how do other birds achieve the same ends?

Partly the purpose is to ensure a sufficient larder. But it is not fundamentally that, for boundaries are less strictly insisted upon when the hectic food search for the benefit of the young is on than at the time of courting and mating, and for that matter the winter method of communal feeding seems to work well enough. When however the birds in the Spring find their sex again, communal life becomes, in a word, impossible. The birds have grown once more into individuals, highly emotional and highly pugnacious and jealous individuals. The territorial system has really these two purposes: to avoid any danger of a species-destroying war to the death amongst the males, and to enable each male to get on with his job undisturbed.

And just what is his job? It is: to get his girl into the mood—that colloquial expression is used of set intent because it does express exactly what is happening. Heaven forbid that there should be any coyness in this description, or any too close comparison with the tortuous and Solomon-confounding ways of men and maids. It is however significant that with both bird and man the same word is used to express this occupation, a pleasanter-sounding and better mannered word at that—*courting*. Courtship is a highly important matter for the male of the bird species, a function to which one might say his whole nature is bent, for which physically he is specially equipped, and in the exercise of which he will use great skill, pertinacity and art.

Birds' equipment for courtship may be an arresting voice, arresting form and colour, arresting action, or a combination of any of these. As for voice, it is good to remind ourselves occasionally for how much of its existence this world has been a silent place, with at best the dim squeaking or thudding of fish, lost in any case below the waves, or the mechanical tiny stridulation of insects, or the monotonous croak of the few vocal amphibians. Even with mammals much of their vocalism seems to us no more than ugly and pathetically frustrated affairs. That is also true of some of the birds. But with others, largely the birds who can fly and so can seek each other, the command of the air has undoubtedly led to another achievement which is the subtle and beautiful control of sound. Flight too gives as nothing else can give much of the rest of the bird's gorgeous equipment for courtship: the feathered wing is so much more than a mere mechanism, it is a sort of potential mummer's cloak, to be opened and spread dramatically and gloriously.

Pages can be and have been filled with description of bird display. In fact we began these chapters with part of a description of Julian Huxley's of the performance of one of the less ornamental actors, and as for the rest the reader will do best to go to the original sources, the books of such other sensitive and expressive bird watchers and bird lovers as E. Selous and E. A. Armstrong and D. Lack and N. Tinbergen and K. Lorenz and Charles Darwin himself. It will suffice here to remind the reader that display is often a matter of stance as well as of brilliance or gaudiness, that it is often something startling rather than beautiful—some birds suddenly gape at each other and their mouth has a brilliant lining—and that the lengths to which some birds will go in their efforts to impress are to us amazing and even ridiculous. The great bird of paradise in full plumage is about as dressed for ordinary living as Gaby Deslys or Mistinguette for work on the farm. Some of these birds hang upside down to produce their effect—and all without the slightest sign of feeling abashed, which after all is more than any human lover in the same posture, however ardent he was, could possibly manage.

And yet, in spite of all these brilliant virtuoso effects, whether of voice or stance or appearance or acrobatics on the wing, the male bird's performance will quite often have no apparent effect on the female whatever. She is bored, she turns her head the other way. But here let us avoid very carefully any anthropomorphism : we will not say that she is coy, that she is merely exercising the eternal right of the female to be hard to please, that she is only pretending. It is nothing of the sort, it is something much more direct and simple : *she is not ready.*

The male seems to know this. With great good humour—and no doubt he is enjoying himself immensely—he does it all over again. He does it, if necessary, yet again and yet again. And then, at last, he succeeds in his intent. Everything falls into gear : the lady responds. The lady in fact falls in love. And this time I think the anthropomorphism is allowable. For that is surely what does happen : she falls into a new state. The time has become ripe, and with a click she changes into something different, that is to say a creature that is slave to a new emotion, a bird willing to mate.

Obviously however she must not remain in this state, that of the lovelorn creature, indefinitely. She must become the prospective mother, the nest-builder.

We have already described the passerine bird at this stage becoming restless, becoming interested in a particular stretch of hedge. The same sort of thing happens with most birds. They want something but they do not seem to know what they want. Something seems to be building up in them but unable to pass the threshold. Then in many species the male supplies as it were the password, the release. He himself presents his mate with nest-building material—and behold she has passed the barrier, she becomes again the new thing, a nest builder, she is slave to the next innate drive.

And it *is* innate. It was suggested, you will remember, that our young passerine might well build a poor nest at the start. But this is very little, if at all, a matter of lack of experience. If a bird builds badly it will simply be because she may not have fully reached the nest-building stage in her cycle of emotional states.

That is in fact the key to the understanding of the strange avian world. The bird is a creature subject to a cycle of emotional instincts or drives and needing some sign or action to release it into the next stage of its cycle. The bird is a creature of instincts, but those instincts are much more subtle and much less mechanical than insects' : they are a *pattern in time that needs to be synchronized.*

Now there is always a danger in generalizations, however useful and true they may be. And danger here is of giving the impression of the bird as a mechanism. That is about the last epithet one should use : it would be much better to think of the creatures as spiritual than mechanical.

They are for instance great *symbolists.* Nor must we consider it amazing that creatures other than ourselves should practise symbolism. For consider such a universal human symbol as the Flag (we have already commented on its primitiveness) : what could we imagine more charged with emotion, and after all the bird is essentially an emotional creature. To use a symbol is nothing more than to use a sign that will be accepted and recognized by the person to whom we give it. All speech is refined symbolism, but birds have not the advantage of speech ; they achieve their symbolism therefore by means of action.

Male gannets and gulls, cormorants and herons, all present nesting material to their mates. In such a magnificent bird as the heron the act is most impressive, with hoarse cries and elaborate bows. Some male penguins, as is well known, present pebbles to their mates at breeding time—and quite obviously though they may appear ridiculous to us they will appear admirable to their fellow penguins. *Ceremony* in fact runs parallel with symbolism : it is something that the bird not merely loves but needs.

A significant ceremony—one of which men also make a great ritual though in rather a different context—is changing guard. Such diverse birds as eagles and finches, coots and gannets, do this—change guard, that is to say, over the nest at incubating time. Often the 'relieving' bird will bring nesting material in his beak, so that in fact the nest may become much bigger than is strictly necessary, rather as a housewife has to clutter up her home with nicknacks and gadgets presented by a well-meaning husband. Eagles apparently bring large sprays of foliage, which serve as decoration and playthings for the young. The heron arrives with an enormous flourish of wings, and the pair then stand back to back, with necks upstretched while they utter their piercing cries. This is how Mr. B. B. Roberts, who went on the British Graham Land expedition of 1934, describes the behaviour of the Adélie penguins:

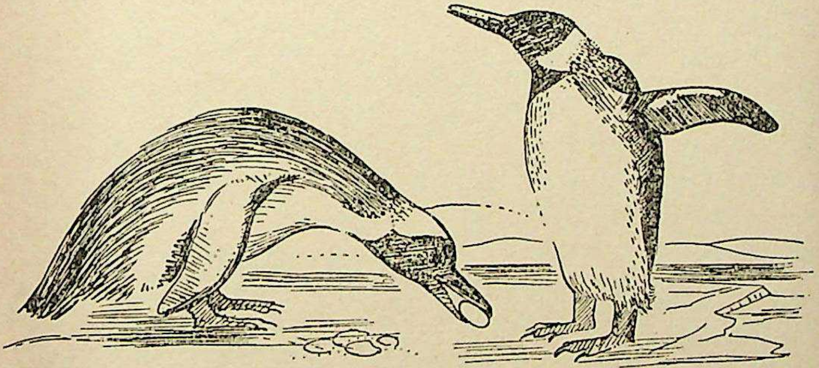


FIG. 41. Penguin ritual

> 'The formality of relieving guard was accompanied by a good deal of ceremony. The returning cock, spotlessly clean and glossy from immersion in the sea, would, on reaching the nest, bow several times to his partner—making a soft gurgling sound in his throat as he did so. He would describe circles in the air with his head, still gurgling; and the hen would raise her head, stretch her neck, and describe circles and gurgle too. This would continue for some time.'

But why all this fuss and bother? we may ask; one would imagine that the hen would be glad to be relieved if the cock were willing. First of all however we must realize that it is obviously not at all a bother to the bird; it seems obvious to all those who have watched them that birds enjoy their ceremonies: it makes them, as we would say of ourselves, 'feel good'.

But then there is this significant description of another changing guard, this time by another sort of penguin, the gentoo:

> 'If a penguin occupying a nest is approached by its mate, it will tend to react aggressively in just the same way as it does towards a strange bird. Indeed it is not uncommon to see one member of a pair peck at the other if the relieving bird arrives too suddenly on the nest.'

In fact, we are back where we were before. However much they may be enjoyed incidentally, these ceremonies are there to create in the partner the right mood, to change him or her from the bird-who-feels-the-eggs-underneath-and-resents-any-intruder to a bird who is merely tired and needs a rest. And if they are performed not quite correctly, too precipitately for instance, they will not work and the response will be entirely the wrong one. It is not, one might say, a very sensible or economical way of running one's life, that the father has to spend a considerable time ingratiating himself and appeasing his mate before he can be allowed to do what she ought obviously to be wanting him to do at once. . . .

The bird in fact is not only an emotional creature but its emotions are a little queer, a little mixed, a little unreasonable. Cormorants for instance will start nest-building as a reaction after the excitement of fighting; many birds will continue to improve the nest when the fledglings have flown away for good. A tit will sing after he has witnessed his mate being killed; and W. H. Hudson tells of a shot bird falling into a stream and, Ophelia-like, singing as it floated to its death. So common indeed is this sort of thing that ornithologists talk continually of *displaced* emotions. They say that a bird's emotions are 'generalized'; it is often as if they might say in excuse for themselves, 'Well, I have got to do *something* to relieve the tension!'

Birds, too, are very susceptible in their emotions to suggestion. They excite each other, by no means only in pairs; they take on a 'crowd mentality', one might say, and elevate it into something, not in the least more reasonable, but more thrilling and exciting, much less sinister, and even useful biologically.

There is a small wading bird not unlike a sandpiper that thrives on the coast of Holland and once did so on our own East Coast; it is called the ruff. Rather, the male is called a ruff, and the female a reeve, and the distinction is justified because in the breeding season the male does in fact grow a surprisingly large and bright ruff or collar of feathers which, with ear tufts, it erects in display. But *not* at the female.

On what is called their 'hill' the male ruffs year by year congregate and 'fight'. And the fight is hardly more a true fight than the hill in flat Holland is a true hill. Each bird has his 'territory', a circle of a couple of feet or so, and it is perhaps the occasional violation of these patches that leads to real pugnacity rather than the more usual ritualized and pretended fights. The whole affair is really a frenzied dance. This is how E. A. Armstrong in his book *Bird Display and Behaviour* describes it:

> 'The birds rush about excitedly and then stop abruptly in a devotional attitude—heads bent low, legs flexed and feathers ruffled. It is a kind of explosive rigidity, and the ruffs may start off running furiously in another direction or sink slowly quiescent to the ground in a manner suggestive of deflation. At times they leap into the air again and again for a minute on end or dance around one another. They peck at the excrescences on each other's faces and scuffle, feint and spar. . . The tenseness of the birds, even more than their frenzied movements, accentuates the impression of sexual stress.

And yet, so far in the proceedings, there may be no sign of any female bird whatever. Some time soon however one will arrive. She will seem to watch the proceedings in a detached manner and then 'with calm deliberation' will choose a male that for some reason pleases, or rather excites her most. She solicits him and they fly perhaps a little way away to consummate their marriage. Meanwhile, contentedly, the dance proceeds. . . .

Now what is the reason for all this? For that matter other birds do very much the same thing, blackcock for instance, their dancing grounds being called 'leks', and hordes of flamingoes in the shallow lagoons of the delta of the Danube. What is the advantage of it? It may, it is thought, be a habit in species where males, or at least males who are experiencing the sexual drive, are predominant. But more particularly and once more, it is a life-saving device. Pugnacity and sexual rivalry are channelled off into harmlessness. A *ritual* has been invented, and the rules of the ritual are strictly observed.

It may be said in fact that these birds have developed a ritual that allows them to live a reasonable social life even at the times of their philogenetic stress. All birds experience a sexual drive, a *libido*, to borrow a word from human psychology; they possess a surplus energy that must find an outlet. Ritual helps them to find that outlet—enjoyably and beneficially, or at the least harmlessly.

They find release too in play. This is not the play of young mammals which is largely a practising for grown-up life, but rather the play purely from exuberance of spirit, and again it is often something ritualized and communal. Ravens fly upside down and dive and somersault together; in Louisiana egrets and herons are said to let themselves plummet down in flocks screaming with excitement. Blackbirds echo each other; wood rails are said to sing intricate duets that are in the same rhythm and that harmonize together, while as to cardinal birds, 'the female interpolates or appends a note so rapidly that only by watching the bird is it apparent that two are singing.' We are indeed back at the communal choiring of W. H. Hudson's 'handsome and loquacious whistling widgeon'. All this is something to set against the picture of the lone bird using his voice as a shouted advertisement and a bombastic threat.

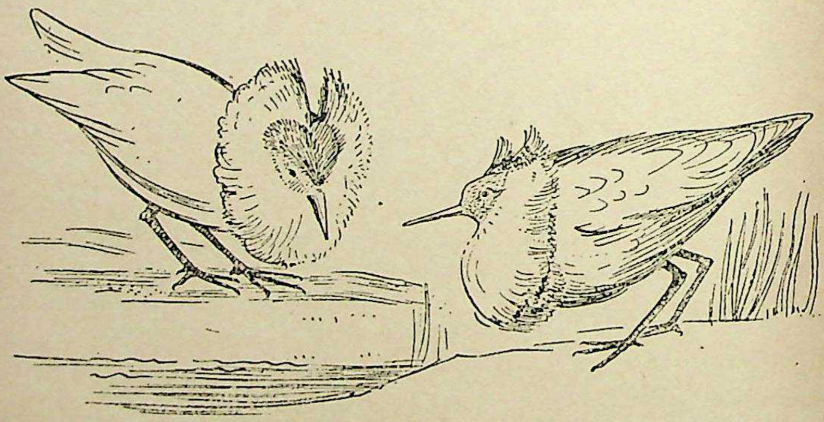


FIG. 42. **Ruff to ruff, not ruff to reeve**

Yet, finally, there is not a real antithesis here. Whether the bird is being singly competitive, or ideally paired, or at times successfully communal, it is behaving consistently. It is behaving in a way very distinct to its kind. For its actions are dictated by a brain that is, essentially, not a rational brain. The bird brain is one upon which things are imprinted, indelibly, either by that pre-natal racial experience that is called instinct, or by the creature's own experiences from the moment that it is born. So at the right moment the right action will be brought up, as it were, out of this deep well of potentiality into fruition and the light of day, and this by the instrument of some symbol, some ritual, some 'releaser'. That is if all goes well. If not—then we have the ridiculous sight of the hen fighting off the 'intruder' because her mind has not worked round to recognizing the helpmeet who has come to relieve her at the nest or the tragic sight of the evicted nestling dying in view of its automaton of a mother. Usually however all goes well. . . .

Except for the growth of the physical attributes, wings and feathers, we have not said much in these three chapters of the actual evolution of the bird. But fossils can tell us little about behaviour. After the death of the dinosaurs both bird and mammal forged ahead and in one way at least the birds had the advantage, in their mobility, so that in great tracts of the ocean and of the arctic they are the dominant form of life above the level of the water.

It is however behaviour, way of life, that is significant. All that we can say is that throughout the Tertiary Period this did evolve. We are in the next chapter going to return to the mammals, in particular the primates: before we do so we need, I think, to get one idea firmly fixed. It is the idea of the basic difference between the three dominant types of life that have finally evolved, the insect, the bird, the mammal. It is a difference based fundamentally on type of brain: the brain of pure instinct, the brain of emotional pattern, and the brain of intelligence and teachability.

We are heir to the last of these—though all brain must have something in common and there are times when bird behaviour and even insect behaviour may be revealing and reminiscent of our own.

CHAPTER XIV

The Other Primates

THE last five chapters have explored what we, being naturally egocentric, must look upon as no more than bypaths, the evolutionary story of the insects and the birds. Whether they are in fact bypaths any more or less than the road that leads to man is an argument not very profitable to follow. One purpose of these chapters was in any case to show that evolution in the later stages of its story is most concerned with the elaboration and perfection of behaviour as a response to environment and a means of conquering and using it. With the Tertiary Period fully established, such problems as the creation of better bodies, better means of respiration, of digestion, of being able to see and hear and smell and feel—physically feel—have largely been solved. There will be elaborations, and variations; but the account from then onwards is upon more subtle and less material things, on—if we can usefully give it one word—sensitivity. Life learns more and more to think and to feel—and this time we obviously do not mean physical feeling.

Equally obviously it is Man who has learnt to think and feel most deeply. The story returns therefore to the mammals, of whom Man is the highest example—it is perhaps high time we returned to them, lest we be in danger of belittling their importance.

But the next step is not to review mind and emotion and sensitivity, culminating in man's ; for we have not yet set out the evidence for believing that man is in fact in the direct line of evolution and a blood relation to the rest of life—we have in fact done no more than call this 'the most controversial statement in the whole theory'.

So it is, so it still is as it was in Charles Darwin's day. But whether it ought to be is another matter. The time is not yet ripe in this book to discuss the theories of evolution ; but let us anticipate to this extent, by assuring the possibly reluctant reader, or the reader rapidly arming himself to resist, that those theories are nowadays by no means so crude or materialistic as they were nearly a century ago. To consider man as one of the mammals and one of the primates, albeit very different and exceptional, is not at all a sickening exercise.

Great play has been made in the past with the idea of 'The Missing Link', the fact that no fossil could be produced that was nicely half-way between ape and man. The position is very different now. The change can be described in two ways : either triumphantly that not one but a whole series of links have been found, or else sweetly and reasonably that there was really needed to be found not one missing link but hundreds and that there have been found now sufficient at least to give a reasonably detailed story. These are but two ways of looking at the same facts.

Before we do so let us first look at something else, some of the indisputable facts that must lead us to believe, however loth we may be to do so, that man is indeed part of the continuous stream of life, actually and not only metaphorically heir to all that has gone before, blood of its blood and flesh of its flesh. Some of these facts are so obvious that they are likely to be ignored or forgotten.

Firstly we are like the rest of life in that we are built up from protoplasm, from cells, and from cells that split and multiply and specialize as the embryo grows. We are also like most of the rest of life, both animal and vegetable, in that new beings are formed by the sexual union of cells from two separate beings. With the rest of animal life we possess systems of organs, that ingest, digest, respire for us ; we have muscles and nerves and senses ; we have a heart, we have blood.

With the vertebrate we have the most striking similarities. We are of that great pattern, of internal skeleton that cages and protects our heart and lungs and brain and acts as the foundation for our limbs, of the pattern of paired limbs—the pattern that has as it were pulsed with the creative urge, to bud forth from fins to legs, to arms-and-legs, to wings-and-legs, to wings only, and with the sea mammals back to fins. We share too with the vertebrates the red blood that carries oxygen as fuel to our muscles.

With the mammals we grow hair, we possess a skull as a good box for a brain and well balanced on a backbone. With the rest of the placentals the race of mankind achieves the miracle of growing the new life to great maturity within its own body, nurturing it with its own blood, and then later—that tremendous tie of intimacy—feeding the new life from its own body.

Finally the primates. In common with most of them we have colour vision and binocular vision ; we have what we may call the unspoilt and unspecialized ground plan of the vertebrates going right back to the amphibians, and we have, in particular, the hand that grasps. As for the anthropoid apes, we have a skeleton that is comparable bone for bone with theirs, peculiarities of blood that are very close indeed, and a liability to catch the same infectious diseases. Later we shall be stressing the differences between man and the anthropoid apes, which may seem a contradiction. But it is not really so. No one in their senses can deny the very close bodily resemblance; nor can anyone in their senses deny the wide disparity when mind and spirit are taken into account. They are two different planes. Bodily—though even here there are significant differences as we shall see—man and the anthropoid apes are very closely related.

Then, returning to the wider kinship of the human race, consider how the new life is formed in the womb. Here first of all, as a change in the weighting the scales, it can be said at once that the earlier evolutionists have claimed too much. It is a well-known fact that a human embryo at an early stage is hardly distinguishable from a fish's, later is hardly distinguishable from a rabbit's, later from an ape's. From that fact it has been asserted roundly that evolution is recapitulated within the womb and that therefore the fact of evolution is once again proved. But even if the statement were strictly true it would not necessarily be a proof of the fact of evolution through the millions of years, any more than a propaganda photograph proves what its caption says it proves or the gyrations of electrons round a nucleus proves that the planets go round the sun. Nor is the statement accurate; it is better to say, as Julian Huxley has put it, that 'ancestral plans of structure may be retained in development', that the embryo of all the vertebrates will begin in very much the same way and will pass through the more generalized forms of its type before emerging into the particular.

But that is surely revealing enough.

Of all the similarities between mankind and the rest of animal life, mammals in particular, it is in the field of behaviour that they are the most striking. But behaviour we reserve for a later chapter—by which time, whether or not the doubting will have been convinced, the ancestry of man and his inclusion for good or ill in the whole picture of life, will have been assumed. One last point must be made however, and that is that we behave with so close a similarity, to the Primates in particular, in our reactions to drugs and medicines: the same substances calm us, soothe us, stimulate us, excite us, send us to sleep or make us wildly uninhibited and gloriously or regrettably drunk. We are brothers under the skin and when we have had a skinful.

Now, in all seriousness, let us get on with the story, that is to say of that particular Order of the mammals called the Primates. It is, besides being more circumstantial, a less confusing and more straightforward story than could have been told even a decade ago.

For the last time we will go back to the evolutionary time scale. The last and originally called third great Era, Tertiary or Cainozoic, is divided somewhat elaborately by use of Greek adjectives meaning 'dawn of', 'slightly', 'less', 'more', 'most', Eocene to Pleistocene; and it is in the Pleistocene, a mere million years or so out of the sixty or seventy million, that man appears. Pleistocene is the age of man as Cainozoic as a whole is the age of mammals. Indeed, to accentuate the importance of this, some paleontologists, as has been said, split off the last million years into a separate Era, the Quaternary, and divide it into the Pleistocene and the Holocene or Wholly New.

We may remind ourselves however that new kinds of life are likely to exist a long time before they flourish. This is certainly true of the mammals, who existed for about as long again as their Era of domination and went their insignificant ways while the giant reptiles still ruled in the last Period of the Mesozoic Era. It is not surprising therefore that fossils of animals very much like what we now class as Primates are found in strata as early as those that represent the very beginnings of the truly mammalian Era.

What is and is not classed as coming within the species of Primate is important, because what is included becomes by its very inclusion our near relative in the Animal Kingdom. Actually this particular classification is a difficult one for the very reason that it seeks to define a pattern of life that has, essentially, insisted on remaining unspecialized. Anyone can class a horse with a zebra, or for that matter, because they all have a split hoof, a cow and a sheep and an antelope. But when the hoof has remained a hand, or rather, to be pedantic but more accurate, a digited appendage, it is not so simple, for the frog and the salamander also have those.

It is the hand, however, as the grasping organ, that has of late been considered one of the most important criterions of Primateship, and that lets in the little tree shrew, that was once put more humbly with the insectivores. The Primates in fact are now usually classed and divided as follows:

- Primates
  - Prosimii
    - Tree Shrews
    - Tarsiers
    - Lemurs
  - Anthropoidea
    - New World Monkeys
    - Old World Monkeys
    - Hominoidea

We have here a rather horribly confusing mixture of Latin and Greek; but there it is, the names have been given and we must use them. The Hominoidea includes firstly Man, secondly whatever human or near-human creatures there have been before our own race of Homo Sapiens, and thirdly the anthropoid or man-like apes of which survive the Gorilla, Chimpanzee, Orang Utan and Gibbon, as distinguished from those of the monkey tribe that are often loosely called apes or ground apes, chiefly the baboons.

First the tree shrew, promoted into our midst. He lives nowadays only in South-East Asia, and though there are many of him and many sub-species, he is not often seen in Zoos. He is small and shy, but a delightful little creature it is said—which, as we know, the ground shrew is not—with a bushy tail and superficially not unlike a squirrel.

On closer inspection he is very little like a squirrel. He has no big upstanding ears, indeed his ears are remarkably like human ears. His teeth are not gnawing teeth. He has claws, but also little hands that can grasp. He has big eyes and an alert expression. He does in fact live largely on insects, but he differs from the general run of insect-eaters partly in those grasping hands and particularly in his brain which is not only big for his size but is given over particularly to response to sight and less to response to smell.

Life in fact had with this little creature gained the first of the advantages of this last chapter of the story. Earthbound smells are losing their overwhelming importance: hunting—and the opposite, hiding and avoiding—are becoming matters of sight, and quickness, and cunning.

Next, something more about the tarsiers than was included in the earlier chapter. What is significant is that whereas there is only one kind of tarsier left in the world, and that only in one corner of it, yet through the twenty-five million years of the Eocene Period he was abundant and widespread. The modern tarsier is in fact an end product and very specialized, with his quite incredibly large eyes and the clinging capacity of his hands elaborated into sucker-ended fingers that seem to us almost an absurdity. The Eocene tarsiers are, as it were, the unexaggerated forbears of the very shy and rather pathetic creature that remains. But they had big eye-sockets; and they had very small snouts.

Those in fact, we may say, are the second and third advantages: stereoscopic vision and a nose that does not have to be followed. Where your snout atrophies you will cease to pick things up by it. You will use your hands instead—and examine what you pick up.

Lemurs and all the monkeys we shall not speak of in much detail. For it seems likely now, as the fossil story fills out, that the direct line to man is not slowly and painfully through them, but more directly, from a tarsier-monkey kind of creature (and some of the fossils are perhaps better so described than as tarsiers proper) to an ape-monkey kind of creature. Modern lemurs and monkeys are also perhaps end products.

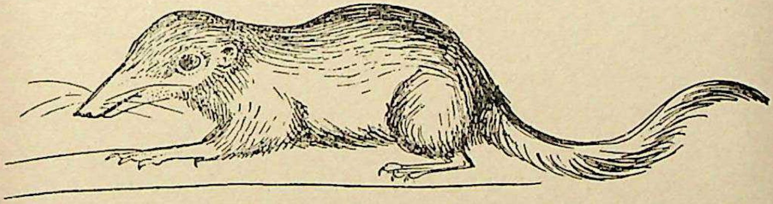


FIG. 43. The tree shrew

That is indeed particularly likely of lemurs, similarly once spread over the tropic and temperate world but later succumbing to more successful types and retiring for a last safety not as the tarsier did into the night but into Madagascar.

That island is the only home of the lemur now, and within its protection he has in the past—as has so often happened with life in the isolated safety of an island—developed in most wide and fanciful ways. There is a fossil giant lemur, 'as big as a donkey', which may in fact have survived until the seventeenth century A.D. and be the animal that the Dutch traveller De Flacourt described as feared by the natives, as well it might be, and given the queerly repetitive and somehow rather ominous name of Trétrétrétré.

The lemurs that are left are neither big nor fierce, though they are bigger than the modern tarsier. They are mild and pretty creatures, nimble climbers, pleasant to meet and make friends with in Zoos. They have by no means entirely lost their snouts, but except for one finger they have exchanged claws for flat nails ; and they are fairly big-brained.

The monkeys are the acrobats of the trees, light and slender of limb and with clever and efficient forelimbs that are quite obviously arms as we understand arms and not merely adapted legs. Their head is shaped like our head, their hand startlingly a human hand.

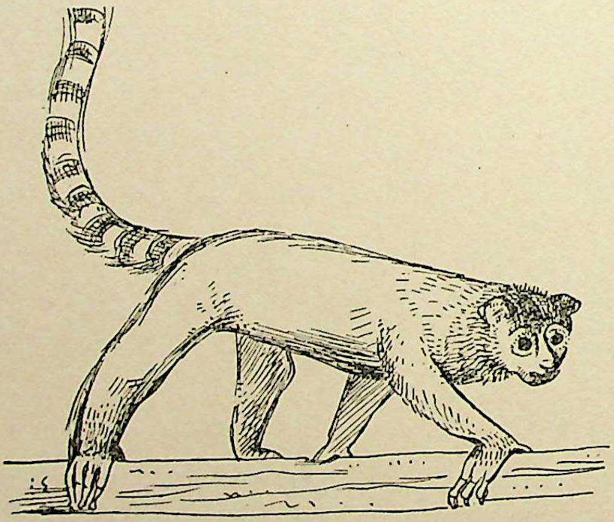


FIG. 44. The lemur

Their feet too are almost human hands. They run along the boughs and use their tail as a balancer.

Three odd and significant things need to be said about the monkeys. The first is that some of their kind, as we believe did man's ancestors, came down from the trees. These are the baboons and mandrils. Either as cause or effect, they lost their tails and put on weight—and ferocity. But they went back to travelling on all fours like the rest of their brothers on the ground (kangaroos and jerboas don't *always* hop) : it was as if the move had been made too soon.

The second fact is that the New World monkeys not only use their tail as a balance but as a fifth hand—it is naked on the inside, sensitive, and prehensile. It has been suggested that as most of them live in swampy forests the need to avoid falling from the tree was even greater and resulted in this extra safety device. The third point also concerns the New World. Nowhere has there been discovered there any trace of evolution beyond these monkeys: the so often repeated parallel evolution of life in separate and separated parts of the world in this instance did not happen. Which may be a pointer to the uniqueness of man.

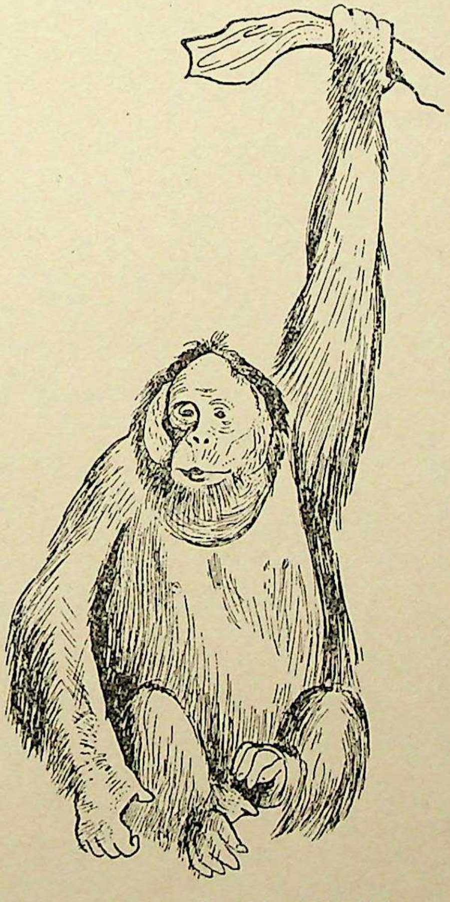


FIG. 45. The clownish orang utan

Finally, some notice of the present anthropoid apes, but again only as end products, only as illustrating what man's ancestors must to some extent have been like after deducting the specializations that the contemporary apes have developed.

The modern apes are, in increasing order of significance, the Gibbon, the Orang Utan, the Gorilla, the Chimpanzee. And the obvious specialization that they all possess in common is their very peculiar, that is to say their very long, arms. The apes do what the scientists call 'brachiate' and what we should more ordinarily call swing with their arms. The most usual mode of progression of the monkey is to run along the bough, using both feet and hands with which to grasp; the ape can also grasp with his feet, but what he does best and most is to swing hand-over-hand. It has given him a specialized arm and even a specialized hand. He has become so good in the trees—watch the spidery gibbon, even in the Zoo he is the trapeze artist and hoots with delight at his own prowess—he has grown so expert that he has never come down.

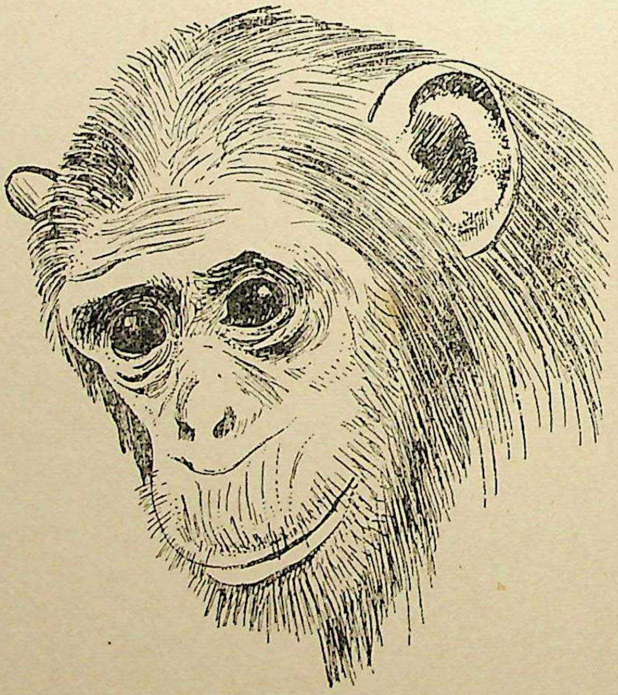


FIG. 46. The sad chimpanzee

Except, partially, the gorilla. That also we mentioned in the earlier chapter; it has been, it seems, a matter of necessity, not choice. The gorilla has become a creature of ferocity and muscle and weight—the trees will no longer bear him. Not only so, but you cannot have muscle without something whereto to tie the muscle, and that shows most startlingly in the gorilla's head. Compare the skull of a gorilla and of a man, and the contrast is quite startling. The back of the elongated skull of the gorilla is one great ridge of bone; his cranium is in fact not a repository of brain, it is a fulcrum for muscles for his cruel jaws. Gorilla is anatomically very close to us, but it is as it were a closeness on the slant, a distortion. Evolution does not work backwards from over-specialization, and this great, sad, lumbering mass of muscle and ferocity could not conceivably be our ancestor—which may be a comfort to those who like for their own torture to distort Darwin who, poor man, was very careful and did but say: 'We thus learn that man is descended from a hairy, tailed quadruped, probably arboreal in habits, and an inhabitant of the Old World.'

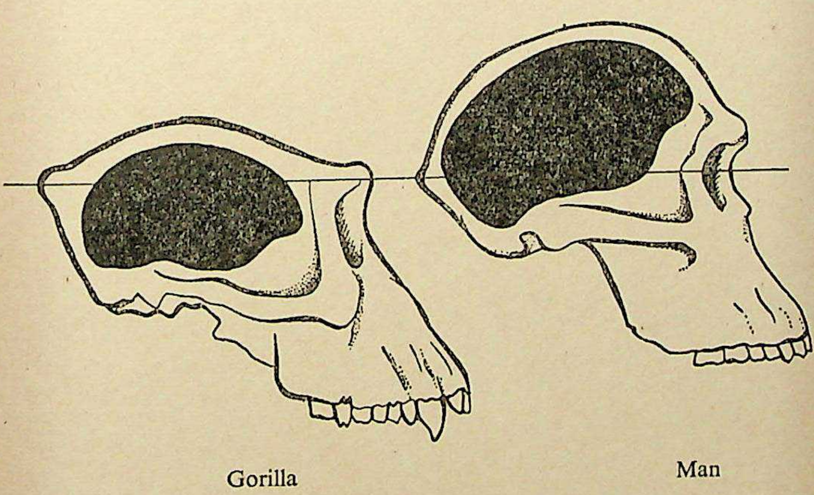


FIG. 47. Contrast these skulls

Indeed all the greater kinds of anthropoid ape (the gibbon is somehow a lightweight in all respects), including the most intelligent and the seemingly most cheerful of them, the chimpanzee, do give an impression both of sadness and frustration, which it is not fanciful to notice. To over-specialize is like having children, it is giving hostages to fortune. And the apes are over-specialized—to life in the trees and in the forest. Trees were a great nursery, even perhaps a harsh nursery; but to stay in them is, we may well say, to stay in the nursery. For to return to the ground with no weapons left, no claws, no fangs, could only be a successful step if there were finally released the improved hand and the improved brain to make together their tremendous destined advance, the manufacture of tools and weapons external to the body.

Man's three fundamental evolutionary successes are probably the making of tools, the control of fire and the invention of speech. But the first-mentioned of these was probably the first necessity—no ape has been observed to do more than poke with a stick or throw a stone. Some say that man does not deserve the title of Homo Sapiens but does deserve the title Homo Faber, Man the Maker, the Artificer, the Smith. The next two chapters will enquire into what has been found up to date about his true origin.

CHAPTER XV

Prometheus Uncovered

OVER the last half century there have been discovered so many fossil skulls and bones and teeth, so varied a collection of the remains of apes or ape-men, while at the same time such fuss has been made about them, so conflicting have been the claims based upon them, so heated the arguments of the experts over them, that the layman may well grow confused and even more than a little tired. In fact he can hardly credit that there is a plain and logical and believable story to be told. Yet it is so ; a plain story does nowadays become possible. Nor must the layman be surprised at the heat that has been engendered in the argument : after all, just what our ancestors were like affects us very closely, it affects amongst other things our *amour propre*. And almost all of us, at some time or another, have become, in the expressive phrase, hot under the collar about the matter.

One help towards a plain and simple story is that as time goes on, and methods of test improve, some of the earlier finds lose their significance, either falling into place and modestly giving preference to later and more important finds or even ignominiously falling out of the running altogether.

That last applies of course to the now famous Piltdown skull, proved to be no more than the cranium of a rather particularly thick-headed paleolithic person to which had been unscrupulously connected the jaw of a modern orang utan or chimpanzee. That means that it is simply best forgotten, even the skull, though old, having no evolutionary significance whatever.

A word about this Piltdown affair, however, before we go any further. The scientists have definitely been convicted of error. They had christened the thing *Eoanthropus*, or Dawn Man, and some of them had built a good deal on to it. But let us be fair to the scientists. Few of them were ever very happy about it, and one at least, the American biologist, R. S. Lull, had declared, long before modern methods of test had revealed the hoax, that the jaw was nothing more than a chimpanzee's. There is the cheering fact too—and no one who knows anything of the methods of Western science would have expected otherwise—that the error has been frankly and fully acknowledged. Perhaps one thing is particularly clear: we ought to be more careful in accepting those so often published imaginative clothings of the fossil skulls with sculptured flesh: none of us has seen a reproduction of Eoanthropus or 'Piltdown Man' with the very distinctive, virtually lipless muzzle of a chimpanzee. . . .

From that, however, it would be wrong to jump to the conclusion that the experts are always indulging in flights of fancy and that nothing worth while can be told 'from a few bones'. A great deal can be told from a few bones. The very fact that even the tyro medical student buys his own human skeleton to study can bring it home to us what a colossal amount has been found out and thought about the human frame. Bones are the fulcrums for muscles; muscles lie along them and make their mark, and so even in fact do nerves. Brain lies within the skull and also makes its mark. We have already mentioned that amazing bony crest of the gorilla that denotes jaw muscle rather than brain; we shall find ourselves soon considering the revealing shape—the quite obviously revealing shape—of a pelvis. Teeth, too, those all-important food-procuring, food-assimilating instruments, can by their shape and arrangement within the jaw, by their number of cusps or protuberances, their more, or less, weapon-like structure, tell us a very great deal about the exact species and the way of living of their past owner.

The discoveries that have been made will now be reviewed, not in the order in which they were made but in the order of what is believed to be their decreasing distance back along the evolutionary line. But before we start let it always be remembered that categorization is always man-made, and can be disputed and in fact is so disputed. Whether an eastern skull should be dubbed *Sinanthropus* or Chinese Man rather than, to invent a title, *Sinopithecus* or Chinese Ape, or whether on the other hand a species of *Australopithecus* can properly have 'man' pushed into its name and be dubbed *Paranthropus Robustus*, is all relatively unimportant. What is important is that somewhere up through the collection of strange and revealing creatures runs the red line, it is believed, of our descent.

The story begins with the laying bare, from a dried-up lake bed in Egypt called the Fayum, of two fossil jaws, whose one-time owners, living in Oligocene times or about forty million years ago, have been given the names of Parapithecus and Propliopithecus. (Not always shall we give these scientific names; but books and even newspapers at times will refer to them as such and sometimes to be ignorant of them is more confusing than having to be weighed down with them. Scientists are singularly free and easy with the Greek and Latin tongues and singularly unforthcoming in explanation of what exactly they mean when they use them: presumably here they mean firstly 'Beyond an Ape' and secondly an Ape living *before* the *Plio*cene or 'more new' Tertiary period). These animals were *small*, the first about the size of the little squirrel monkey, the second of an undersized gibbon. Of the first, Sir Wilfred Le Gros Clark, Professor of Anatomy at Oxford, says: 'So far as it is possible to make inferences from such a small fragment, *Parapithecus* seems to have been a small anthropoid ape of a very generalized kind which still retained traces of its origin from a tarsioid ancestor of Eocene times', and of the second that it had reached 'a stage further' in the line of evolution that has led to the anthropoid apes of today.

The soil of Africa was however to yield very much more than these and the story gives a leap forward with the discoveries in Kenya in the 1940s by Dr. W. H. and Mrs. Leakey.

These again started with a jaw. Its owner, with a refreshingly unscientific but romantic enthusiasm, was christened *Proconsul* and the scientists have rather surprisingly accepted the title. That was in 1942. Six years later a complete skull was found by the Doctor's wife; and, having prudently insured it for £5,000, she promptly flew with it in her lap to see what Professor Le Gros Clark could make of it. This was followed by limb bones and in fact a whole series of remains of skulls of this and other types of primitive ape-like creature—of all of which the experts have between them made a good deal. They show much more clearly, these fossils of Proconsul's contemporaries, that they are indeed all of a 'very generalized kind'. They are, in short, *less specialized*. They are lighter in build, their arms are not ridiculously long tree-hanging hooks, their nether limbs have not semi-atrophied. Their head is set in a way that would have made an upright posture easier; their canine teeth are not great tusks; there are no great ridges of bone in the skull to carry the muscles of a super-jaw. Without any doubt these fossils show us animals such as we would have expected if we are right in regarding the modern ape as a collection of aberrant specializations away from an ancestral type from which we too could have sprung.

Not only that, but the Leakeys by their hard work have shown us something else. For the work, though difficult, was so very well rewarded: East Africa seems in fact to have been a sort of forcing ground for the Apes. In a *Pelican* book by Sonia Cole called *The Prehistory of East Africa* the author tells how in spite of the difficulty of picking out in the glaring white of the lake-bed the wanted fossils from the strewn bones of crocodile and tortoise, in spite of the depredations of prehistoric hyaenas who had been there first, there have been gained from this one small island of nine miles by five in Lake Victoria several hundred ape fossils including at least three genera and six species, ranging in size from a gibbon to a gorilla. This seems to denote one of those startling exuberances of the evolutionary process, one of those sudden burstings-forth that have occurred many times before and which must have their great significance.

From the forcing ground of Africa the anthropoid apes seem to have spilled out across tropical and sub-tropical Asia and Europe. Their creation—their evolutionary creation, that is to say—was, by the fossil signs, in early Miocene times, some thirty millions of years ago, and they spread during the rest of that Period and beyond. Their remains, some of them discovered many years earlier than Proconsul and his relatives, have been given various names, of which Dryopithecus or Ape of the Woods, is the most well known. He too remained a comparatively unspecialized and a lightly built and agile beast.

But so far there is nothing the least human in these remains, only the clear indication that the apes as we now know them did not exist in the past whereas what did exist, as probable ancestor of both ourselves and them, was a creature considerably different, more limber, less locked out from further progress in brain and limb by a fortunate lack of blind-alley specializations.

For the next step we stay in Africa but go farther South to the Transvaal and survey the finds of two most enthusiastic scientists, Dr. Dart and Dr. Broom, which range in date from 1924 to 1948. We move a great way too in time, at length to the Pleistocene or Period of Most Recent Life, to the final single million years of our planet's history.

Dr. Dart, Professor of Anatomy at Johannesburg, did not actually make the discovery of 1924; he recognized its significance. The discoverer was a quarryman who blasted from a limestone deposit at Taungs a small skull which he had the knowledge to recognize as unusual. Most of the case of the skull was there, and the jaw and the teeth. The teeth were milk teeth, of a child of about five years. Dr. Dart without delay issued a description, claimed for it a new species which he called *Australopithecus Africanus* (Southern Ape of Africa), and said boldly: 'The specimen is of importance because it exhibits an extinct race of apes intermediate between living anthropoids and men.' The scientists were a little scandalized and sceptical—it is after all their inalienable right to be sceptical—talked of 'Dart's baby' and of his precipitous rushing into print. However, further discoveries in the area, by himself and others, have completely vindicated him.

His chief supporter was the Dr. Broom already mentioned, a Scots doctor of medicine who, after a varied and adventurous life, and at that time nearly sixty years of age, was working in South Africa on the evolution of mammals from reptiles. He came early to see Dart's baby, was convinced of its importance, and pretty well spent the rest of his long life searching for, discovering, analysing and publicizing the Australopithecine family. There are many stories of the enthusiasm, the successes and the near failures of this rather wonderful old man. He would do such things as rush across the countryside in his car to rescue from oblivion a skull found by a schoolboy, to transfer priceless prehistoric teeth from the boy's casual pocket to his own. He died in 1951 at the age of eighty-four, and by then he had supplied the world with remains from more than thirty different specimens of these Pleistocene apes of South Africa. It was the teeth of the original baby's skull—or rather one particular tooth, so fine and meticulous had become this business of classification—that did most to persuade the experts that Australopithecus marked an important step in evolution. Doctors Dart and Broom prised apart the fossilized jaws, and the lower molar of this jaw of milk teeth showed a patterning of the all-important and revealing cusps that no modern ape possesses but that the modern human child does possess.

By now Australopithecus is thoroughly documented and described. His height was the height of pygmy men. His brain was the size of a modern ape's brain or a little larger. But the shape of his head and particularly of his forehead was a little more human.

So were his limbs. And what was of particular significance was the manner in which his head was balanced on his spine: it seemed highly probable that he, very nearly, walked upright.

It was one of Dr. Broom's most lucky finds that clinched the argument on this last most important point. The shape of the human pelvis is entirely different from the shape of the pelvis of any ape and it is so because the human bone has both to help support the guts and also provide the necessary area for attaching the quite distinctive muscles that enable men to walk balanced upright upon the ground. The almost complete and extremely well preserved pelvis of Australopithecus that was discovered was in shape almost exactly a human pelvis. *Here was an ape that walked.*

Nevertheless on balance, one still had to say 'ape'. The creature's brain was small; and nowhere with its bones had there been discovered any sign of flint tools or weapons. The bones of many kinds of prehistoric animals were found with it in the limestone caves, which animals it perhaps trapped and ate; and some of the baboon skulls were bashed in—perhaps Australopithecus did the bashing. But no more.

For the next step in the story we shift to Java and China, and to a discovery so comparatively long ago as 1890. A Dutch anatomist, Eugène Dubois, had been inspired, it is said, to an interest in the origins of man by the long and fierce debate, proceeding while he was young, over yet another skull, the significance of which has now somewhat lessened. That was the Neanderthal skull (of which more later). Dubois, wisely expecting to find the sort of evidence he was after where there lived the surviving apes, and for certain reasons favouring the Indo-Malayan regions to which in any event he had, one would imagine, easier access, got himself appointed an Army Surgeon and in 1887 sailed for the Dutch East Indies. At Trinil in Java, as a reward of various diggings in three consecutive seasons and over a stretch of some fifty feet, Dubois discovered the best part of a jaw and cranium and also a thigh bone. Exactly the same picture was given by them as by *Australopithecus*—though this of course was as yet unknown—of an animal, that is to say, small-brained and with an ape-like head but with the stance of a man. Dubois, impressed particularly with the evidence of an upright stance (as he had every right to be) christened his find '*Pithecanthropus erectus*', the erect ape-man.

Again there were shouts of disapproval, rather louder shouts indeed than against *Australopithecus* because the controversy, the religious controversy, over Darwinism, was still a thing of the very recent past. How in particular, people asked, did Dubois know that skull and thigh bone belonged to the same skeleton?

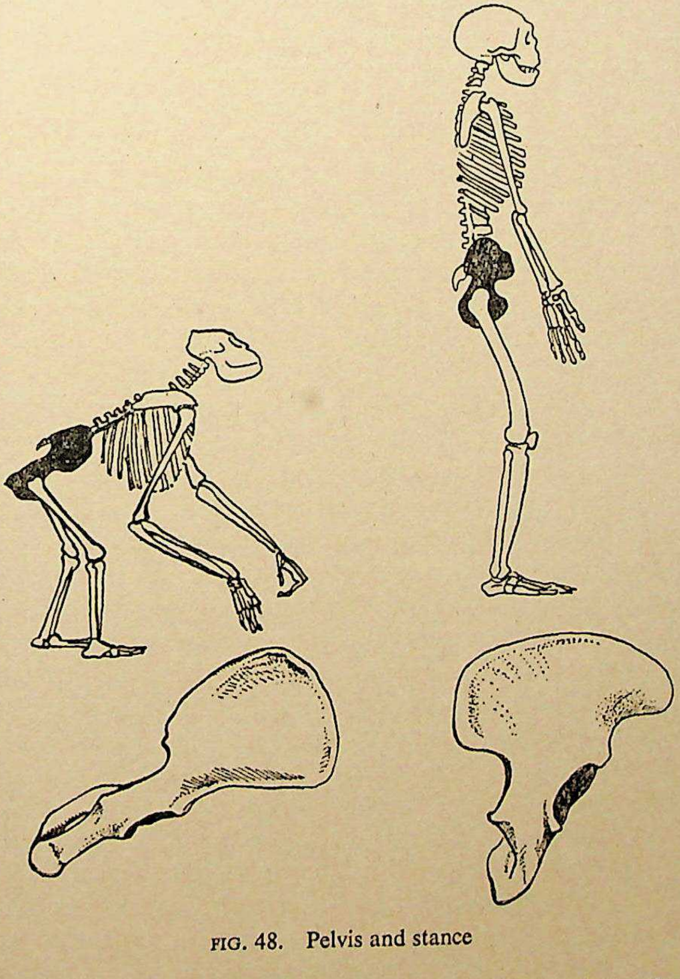


FIG. 48. Pelvis and stance

The answer is of course that Dubois did not know but only had a shrewd idea. But we need not follow the argument further because, as with the South African finds, a far larger number of remains have of late years been found, so that the form of these creatures of Java has been defined and Dubois vindicated. It is worth noting however that one result of the controversy was that Dubois took umbrage and locked up his bones—together with the remains of two other skulls about which he had not said a word—and did not unlock them for a full thirty years, when the pleadings of fellow-scientists or perhaps the mellowing influence of age eventually caused him to relent—from which we may gather that anthropologists are as human as the rest of us, if not more so.

In one particular way does this Eastern Pithecanthropus differ from African Australopithecus, he has a bigger brain: in other words Dubois' original claim to have discovered a creature with man-like attributes, that had a title to have '*anthropos*' in his name, has by now been fully accepted. The further finds in Java that helped to justify the difficult Dubois were made in the 1930s by a young German palaeontologist, von Koenigswald, and they included a skull that was almost uncannily the twin of Dubois' and also, as in Africa, an infant's skull—this time not much over two years old.

All these finds build up to a creature broad-nosed, prognathious jawed—that is to say with the mouth jutting out beyond the nose—thick-necked, chinless and foreheadless and with prominent ridges above the eyes. Why, it might well be asked, should such a creature be called man-like? Even size of brain, bigger than any existing apes: is that necessarily a criterion? A good answer has come from the discoveries made at a Chinese village near Peking.

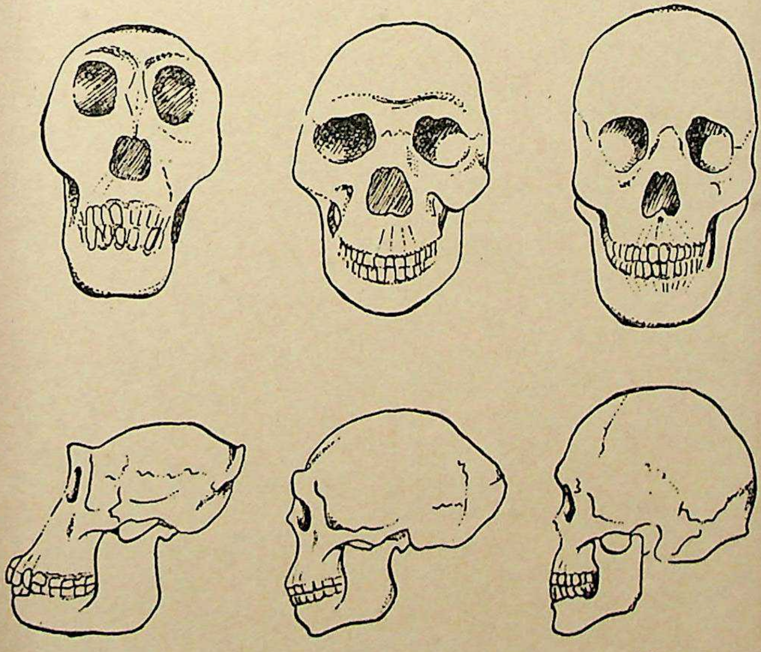
Once more it is the story of an enthusiast getting himself posted to the scene of action, this time a Canadian by the name of Davidson Black. Dr. Black became a professor at Peking University. In his youth he too had been enthused by an earlier find, no less than the ill-starred Piltdown skull—which fact perhaps even justifies its existence.

Near this Chinese village is 'Dragon-bone Hill', once riddled with caves and as full of fossils as its name implied. There Dr. Black, and later his successor Franz Weidenreich, made their finds. It started with one tooth. And so anxious have been these discoverers to stake their claims, or so meticulous and accurate had become the comparative analysis—you can look at it in which way you like—that Dr. Black claimed a new species, *Sinanthropus* or Chinese Man, on that one tooth.

And yet, once again, vindication has followed—though not perhaps absolutely. *Sinanthropus* has been allowed, but only as a separate genus—a slightly bigger-brained genus—of the species already discovered in Java. Peking Man becomes in fact absorbed by Javanese Ape-Man and the definition *Pithecanthropus erectus* may be said to cover both.

We come back then to this same Eastern creature originally discovered by Dubois, and we can now answer the question: Why should we be so certain that we can call him human? The answer lies in what had also been discovered in the caves of Dragon-bone Hill. By the time Pearl Harbour and the Japanese war had put a stop to it, the excavations near Peking had laid bare a good deal more than the remains of over forty individuals; they had uncovered piles of bones of a variety of mammals that the Pithecanthropoids had eaten, a great number of primitive stone implements, and the evidence of the controlled use of fire.

Now how much mere size of brain is significant can be argued over interminably, but by their fruits ye shall know them and it is the results of the exercise of brain that matters. If Pithecanthropus had



Gorilla Pithecanthropus Man

FIG. 49

begun to shape tools and control fire—and there can be little doubt that he did—then he *is* Man and we cannot surely deny him his relationship to ourselves.

Pithecanthropus erectus, perhaps the real Prometheus, lived just about half a million years or twenty thousand generations ago. That is not very long in which to produce the fine and handsome-headed painters of the caves of Cro-Magnon who thrived about 20,000 B.C.

CHAPTER XVI

And So To Man

THERE is still a lot of ground to cover; we cannot jump from 500,000 to 20,000 B.C. in the cavalier manner of the end of the last chapter without some effort to fill in the gap. In what follows two things should be remembered: the generalizations will sometimes have to be wide; and the picture, which can only be given as at the time of writing, is likely to change at any moment—at the least in detail—since new discoveries of some sort seem nowadays to roll in almost every month.

The two great milestones so far, after leaving the various more unspecialized tarsoid-like, ape-like creatures that could have been ancestors of both ourselves and the present anthropoids, are in turn Australopithecus from South Africa and Pithecanthropus now promoted to Sinanthropus or Chinese Man. The first had a brain about half the size of ours, the second about two-thirds, and both are pretty brute-headed, heavy jawed and chinless. Both, that is to say, were a good long way from Homo Sapiens—though both could walk upright. Sinanthropus lived, it is believed, half a million years ago; Australopithecus' dating is a little more uncertain, but it seems to be something the same and the expectation is that further finds will prove him to be earlier. Both, it would appear from the other fossil finds about them, had some ascendency over the beasts around them, often larger and more frightening beasts than now exist. Sinanthropus made crude tools and in his cave was found the first hearth.

Now where do we go from there? We have for the rest of the story new factors, each of which both complicates and helps matters. The first is the recurring Ice Ages. The latter half of the Pleistocene Era, the last half-million years, is the time of the bitter rhythm of these recurring scourges of life: it reduced the mammals from their heyday to our present comparatively chastened and impoverished selection; and it tried the Primates to the utmost, presenting them, we can only believe, with a terrific challenge. There were four of these Ice Ages or glaciations, three remarkably mild periods—with hippopotami on the Thames in the intervals. These help the paleontologists to date their finds.

The second new factor is that here is now found and there has now to be taken into account not only bones and skulls but the flint weapons that their owners had used—geologists' terms give place to pre-historians', Pleistocene to Paleo- and Neo-lithic, Old and New Stone Age. With the New Stone Age, beginning about 7000 B.C., there comes the change from hunting to agriculture and we are virtually in history: it is the Paleolithic with which we are more concerned, and that goes back to the very beginning of the making of tools and weapons and so in fact back to Sinanthropus. It will I think make for clarity if we in fact now trace the story backwards. This will also serve to bring us to a most recent discovery that will very well point the story. Go back from the end of the Old Stone Age to roughly 20,000 years ago and you are in the age of the skilled flint workers, the cave painters and the perfect specimens of Homo Sapiens, and you have arrived at the edge of the last glaciation, the final retreat—we hope—of the ice. Back beyond that however a curious thing happens: the predominant finds are of a most brutish type, chinless, beetling browed—and shambling. This is the famous Neanderthal Man.

Neanderthal Man has caused a great deal of bother. The first specimen was discovered at Gibraltar in 1848: nobody took much notice—it was before Darwin. Then in 1856 was discovered in Germany the skull that gave the race its name, and in 1886 two more, and now a great deal of notice was taken. Was this, people asked, the Missing Link?

In plain fact it was nothing of the sort. And in plain fact Neanderthal men, or men obviously related to them though enthusiastic discoverers may have given them other and special names, have since been discovered practically all over the world, at Broken Hill in Rhodesia, at Mount Carmel in Palestine, on the Solo River in Java not far from the finds of *Pithecanthropus*, and lately, confirming the Rhodesian find, at a place called Saldhana Bay near Cape Town. Indeed the Neanderthalers were a successful and prolific race. They used the 'Mousterian' type of flint, which is made, with some cleverness, not from the original core of stone but from a flake already knocked off, and they had a brain in size often bigger than our own.

But they were so different from ourselves, and at the same time so comparatively recent, that nobody now believes that they can have been our ancestors. The more recent skeletons even tend to be more heavy browed and thick skulled rather than less: the race seems to have run to exaggeration and over-specialization and so to extinction. At any rate it ran to extinction.*

Where then are our ancestors? Our own country is believed to give the answer. The South-East corner of England has so far surrendered three famous specimens, and two have been unlucky, 'Piltdown Man' supremely so and the Galley Hill skull comparatively so since modern inexorable methods of dating have pushed it forward to the Neolithic. But the third, the remains of the Swanscombe Man, does something to redress the balance. The only trouble is that there is not much of it: two large parts of the skull but no part of the face or jaw.

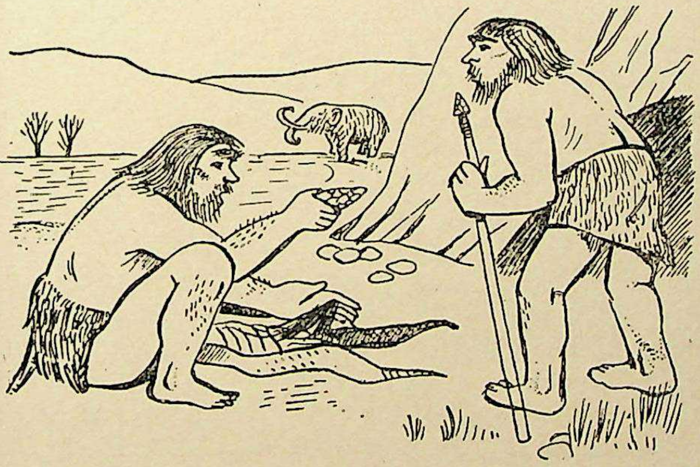


FIG. 50. Neanderthal Man

There are a couple of very important points about this find. The first is that the curve of bone fits almost exactly to that of a modern skull. The second is that the animal bones and flint implements found with it date it undoubtedly in an interglacial period—and the last of these periods was a hundred thousand years ago and the previous one a quarter of a million. In other words the existence of

* For a brilliantly imaginative reconstruction of that sad event—sad at least for the Neanderthalers—read William Golding's novel *The Inheritors*.

Homo Sapiens has been pushed back from the once believed mere tens of thousands of years to the hundred or hundreds of thousands. This Swanscombe man was thick skulled, perhaps he was a little beetling browed; but that he could have been anything like either Neanderthal Man or even Sinanthropus these meagre finds show to be impossible. Perhaps in the same way as the little mammals were hanging on and waiting their chance while the giant reptiles thrived, so the immediate ancestors of Homo Sapiens were hanging on through one or two great Ice Ages while the Neanderthalers thrived.

To link back from Swanscombe Man to the upright but ape-like men of Java and the Peking caves, there are two outstanding finds—everything here seems to be going by twos. One is the skull found at Steinheim in Germany in 1933—probably older than the Swanscombe finds and neatly fitting into the picture by showing rather ape-like jaw and forehead but a braincase that is filling out at the back to be nearly as big as our own. The second is better known because longer found: Heidelberg Man of 1907. This is a jaw only. It is massive, chinless, ape-like, but the teeth are very nearly human teeth, small for the size of the jaw. Its age is about the same as Sinanthropus—mid-Pleistocene, up to half a million years old: it might be called Sinanthropus transferred to Europe and with more nearly human teeth.

But this is all rather bare and dull. Backwards from Cro-Magnon cave-painter, through Swanscombe Man and Heidelberg Man to Sinanthropus: what were they all like? We have talked of the significance of tools and have then said nothing about them.

The truth is that neither the Swanscombe nor Heidelberg remains had any tools with them—we don't know what they used.

But we have on the other hand a tremendous amount of tools without fossil remains. And one of these types of tool persists, with many variations but fundamentally the same, for something like 200,000 years. This is the 'hand axe', shaped from a central core of flint to fit into the hand at its rounded end and having both a double cutting edge and a point, veritably a universal tool and weapon. Nevertheless that it should have lasted so long is almost incredible. It shows the beginning of tradition, and the lasting strength of tradition. The flints found with Sinanthropus vary greatly—they are shots in the dark, clumsy trial-and-error efforts; but here is something different, something knowledgeably copied from generation to generation. Apparently Homo Neanderthalensis did not use this tool; who, then, did?

Once again in Africa we get the answer. First of all there is the site of a Middle Pleistocene lake bed not far from that 'forcing-ground' of apes in Lake Victoria. This must have been a forcing-ground of men. Hand axes of the earliest type lie strewn over the ground—'tens of thousands of them'—and there also are the bones of the prehistoric beasts that these hand axes helped their owners to kill and flay. They were big and fierce beasts, a giant pig, a giant baboon (unpleasant eating surely), a curious goggle-eyed hippopotamus, and *sivatherium*, sufficiently described perhaps as a 'short-necked and antlered giraffid'. This site teeming with remains gives the impression of a courageous and a thriving people; there is even a suggestion that they used the 'bolas', an ingenious instrument of three stone balls tied together with thongs—*trios* of balls have been found—and thrown into the herd to entrap the feet of the intended quarry.

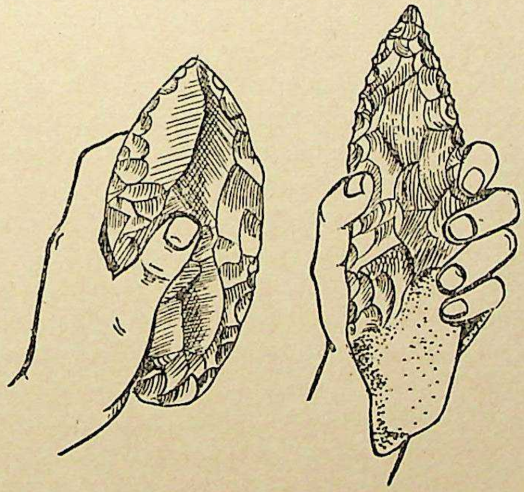


FIG. 51. Hand axes

But, tantalizingly, not a single human remain has yet been found.

Then in the summer of 1954, in Africa but a different part of Africa, Algiers, the Department of Oran, were found two fossil jaws lying near to these same early type of hand axe and the broken bones of much the same sorts of prehistoric animal.

Professor Camille Arambourg, who discovered them, tells how the site, a sand-pit, had been known as a likely place ever since it had been created in the building of a nearby village in 1872; it was however close to a Moslem cemetery and only in 1952 was permission granted for further digging. Patience was rewarded.

The discovery is sufficiently outstanding. For these jaw-bones—they are given the name of the Tenerfine jaws, and their owner the scientific name of *Atlanthropus mauritanicus**—are described as 'massive and brutal' and in fact almost identical in dimensions and proportions with those of Sinanthropus of Dragon-bone Hill. In other words the users of this first traditional tool that was to continue until Homo Sapiens appeared are none other than close relations of the prehistoric man of China, first called Pithecanthropus or Ape-Man. If that remains uncontradicted it means that our ancestors, even when they had achieved an upright stance and the use of a good tool, were still relatively small brained and still relatively brutal in appearance.

The details however of this long story of Man's origin will no doubt change as more discoveries are made. What does seem now reasonably well established is a steadily traceable lineage right back to an unspecialized, bright-eyed and clever tree-living creature. Then, millions of years later but nevertheless farther back in time than we had supposed, our ancestor came down from the tree and at once—relatively speaking of course—achieved an upright posture and an ability to make tools. Then progress was, by human, cultural standards, tediously slow, by biological standards, dramatically quick.

And the cause of that antithesis is *brain*, the growth of consciousness and of mind. An entirely new factor, an entirely new standard, appears. . . .

The evolution of the sensitive mammalian consciousness—brain and behaviour, "heart" and mind—will be the subject of the next trio of chapters.

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* From *La Nature* of November 1954.

CHAPTER XVII

Sex and the Meaning of It

> What a piece of work is man! how noble in reason! how infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a God!

EVEN the only too obvious fact that man does not live up to his potentialities is part of the picture. Man is a unique creature, subtle, sensitive and complex. He is the culmination of the mammals, and he excels in what is undoubtedly the mammal's outstanding characteristic, intelligence. Yet how misleading it is to say that, baldly. We have called the insect a creature of instinct and the bird a creature of emotion; and if we have to give one word to epitomize mammal and man it would have to be intelligence. It is far better not to give one word. It would be nearer the truth to say that the mammal's brain, and man's too, is intelligence tinged with instinct and highly coloured with emotion. If mind comes increasingly into the picture the body does not go out.

The next three chapters will try to do for mammals and man what the earlier chapters did for insects and birds. But the creatures to consider are more complex and for this reason we shall have to range wider and farther: in fact the chapters consider the evolution of sex, and of brain, and then of their combined influence upon mammalian behaviour. It is, if you like, a saga of increasing sensitivity, culminating triumphantly in Man.

But the story is not always heroic or even very pretty, the sensitivity being at times and especially at the beginning more than a little masked.

Sex begins certainly on a very lowly and physical plane. It also begins, surprisingly, not as an essential of life's reproduction but as a complication of it, an intrusion into it. Life can proceed without sex. For reproduction is essentially, and need be no more than, a sort of amplification of growth. Through some inner urge, some excess of energy, the cell divides: where there was one life there is now two. Where you have sexual union you need on the other hand two lives to produce one more. True the original lives have not sacrificed themselves, they still exist, at least for a while. But even so you have only three lives for two, not two for one. At the very least there is a slowing down, on the face of it an unnecessary complication. What then is the advantage, for sex if not universal is to say the least highly prevalent. The answer is really well known: *the stocks are blended.* It is rather like presenting the engineer with the invention of alloys, or the cook with a well-stocked store cupboard, or the artist with all he needs in the way of paints, the musician with the piano keyboard: Evolution gave itself the tool it needed—or, to be more accurate and as we shall see in a later chapter, one of the two tools it needed—and the creation of variety was made possible.

But, though it was never to usurp totally the function of reproduction, sex cannot have been long in arriving. One of the remaining simple single-celled emanations of life, the slipper animalcule, has a peculiar and revealing habit. If a culture of these innocent creatures, splitting and perpetuating themselves, is found to slow down and as it were lose heart, a fresh strain may be introduced. If this is done some of the new animalcule may be seen to pair up with individuals of the old school and slowly to exchange a part of their nuclei. Other one-celled creatures actually coalesce together. And these unusual occurrences seem to have a revivifying effect, the more ordinary process of simple fission being speeded up again. It is rather the same with a much more complicated creature, the green fly and black fly of our gardens, who throughout the summer increase alarmingly by a simple process of virgin births but who when the hardship of winter is approaching produce more vital stock by the slower but apparently more potent method of sexual union.

The essential sexual process—to recapitulate a little on earlier chapters—is to produce two types of specialized cells, one the ovum, the primarily passive functionary, to await fertilization and then to begin the process of forming the new life; the other, the active sperm, to seek out the ovum and to function as both the releaser of the process and also the contributor of its own characteristics to the new life about to be formed. It is as if he who pulled the starting switch gave some of his life blood to the process to boot, as if the shilling in the gas meter were also half turned into gas.

Yet even that is not sex as we know it. Nature is remarkably economical at times besides remarkably wasteful. There is nothing to prevent one creature producing and housing both kinds of cell, ovum and sperm, male and female. And that is in fact what happens in many forms of primitive life—as well as, incidentally, by accident in other forms up to the highest: the hermaphrodite. If hermaphroditism is to be the method, however, the principle of cross-fertilization must not be forgotten. The common earthworm is hermaphrodite; but earthworms lie together and exchange their sperms. Sponges—to go back evolutionarily to one of the most primitive of many-celled creatures—are hermaphrodite. But they have the waters of the sea to help them. And so they congregate together on the rocks and ledges of the sea-bed, and send out their ova and sperms largely at the same time, as if at a given signal.

And that one fact is revealing, for in it lies the beginning of all that leads to the courtship of birds and beasts and men. It is indeed a very materialistic beginning. It is the simplest solution of the age-old problem of ensuring that place, time and individual—one can hardly say 'loved one' at this stage—shall be all together. To put it colloquially, if you want a thorough good mix-up for the next generation, give your marrying cells the best chance of meeting by sending them out into the world at the same time.

There is the remarkable palolo worm and its as nearly remarkable relation the rag worm, to which we gave the more scientific name of Nereis in the earlier chapter. They both have their breeding season. As this approaches the rag worm startlingly changes its appearance. At the hind end the intestines atrophy and the swimming bristles do the reverse; at the front end eyes and feelers grow respectively larger and longer. When the transformation is complete the rag worms swim to the surface of the sea, discharge their germ-cells—and then die.

The palolo worm does much the same but actually breaks in two, only the back part swimming to the surface to spawn. But what is more remarkable is with what precision all do it at the same time, to whit on a certain night depending on the phase of the moon, and so regularly that the natives of the Pacific have learnt their custom and depend on it to provide themselves with a traditional feast, the urge of one lowly form of life leading directly to a ritual in a higher.

Two influences, that are allied, are in fact at work. The first marks the appearance of some forerunner or equivalent of what in vertebrates are known as the hormones, those chemical messengers coursing through the body that have an effect so incomprehensibly out of proportion to their bulk. The sex cells, the so-called gonads, from becoming separate and important as they do immediately many-celled life develops, now become powerful; they ripen, and behold there is at once sent out an influence that alters the whole form and the whole remaining life-cycle of the creature.

The second influence is perhaps stranger; it is more primitive and at the same time may provide some clue to the queerer behaviours of man in the mass. The glands that produce internal hormones are called *endocrines*, which from the Greek means 'sifting inwards'. But there are also secretions that sift outwards, *ectocrines*—the scent glands of mammals are an example—and these also must exist and be at work in these curious mass-behaving palolo worms. Sea urchins, and star-fish, do the same thing: in plain, but accurate, language, one in spawning *sets off* the others. It has, where there is as yet no internal insemination, an obvious advantage: it ensures that the casting of germ cells into the water, whether by hermaphrodite or single-sexed creatures, shall not be entirely haphazard.

Nor need we look upon hermaphroditism with disgust. Even in the highest forms of life physiologists tell us that sex is not something constant and immutable; it is rather a matter, as between one sex and the other within an individual, of potentiality, of a balance that as the new life grows falls down on the one side or the other—and may even change. In less individualized forms of life hermaphroditism is no more than a sort of simplification, almost one might say of having the best of both worlds. Its possession does not even—in fact does not in the least—preclude a quite elaborate love-making, a quite gracious courtship. This is true of the common garden snail.

These slow but purposeful creatures, with their shells on their back, are described as first circling round one another, finally meeting, and there caressing one another with tentacles and lips and devouring the slime—leave but a kiss within the cup!—from one another's bodies. Then a most curious thing happens: one prods into the other what are called—poetically, this time—'love darts', small calcerous spikes that have been developed for this essential purpose of producing in the partner the necessary mood or the necessary physiological state of response—which is the more correct description it is not possible to say. As for slugs, there is a certain large kind that, when the mood mutually overtakes them, crawl along the branches of shrubs, to meet. There they each, like caterpillars, spin a mucous filament, and descend by it. As they descend the two threads become intertwined, with the inevitable result that like the ends of a child's twisted skipping-rope the two bodies gradually come together; and then, suspended, they mate. That is an astonishing thing. What unconscious urge, what cranky instinct, makes them perform the essential function of their lives in such a fantastically complicated way?

But the evolution of sex, in animal life at least, finally discarded hermaphroditism as, apparently, nothing more than a possible but not very promising method. True male and female became the general rule; in the Paleozoic seas courtship, already begun one must imagine from these examples, must have continued its long history.

Yet why courtship at all; wherein lies the real need for it? The answer has really already been given, in the chapters on birds, the creation that has brought behaviour to the forefront of the picture by the outstanding elaborateness and formality of its pattern. Courtship is the means for ensuring that the reproductive act shall proceed and produce the most successful results—it is at it were the individualized sublimation of the mass use—the 'crowd mentality' effect—of the ectocrine glands. And it is not, let it be understood, a degradation of the word 'courting' to use it thus; the way to look at the matter is not that love and love-making have a degraded beginning but rather that a highly practical and physical matter has become so private, so personal and finally so spiritualized.

Cephalopods change colour—there is no reason why we should not consider this any less a matter of emotion than the maiden's blush, though a less mind-directed emotion no doubt. Male crabs wave their claws wildly, take on a more vivid hue in the breeding season, perform what can only be called dances in front of their lair and before the female. Indeed the one thing above all others that must impress the reader of the curious mating habits of all the more primitive classes of the animal kingdom is how closely they ally themselves, though they may not be so spectacular, with the behaviour of birds. There is the same display of colour or movement or a combination of both, the same mixture, and not always very efficiently segregated, of aggressiveness, meant presumably for the rival male, and enticement meant for the female, the same preoccupation with territory, the same apparent indifference of the female and the need quite often of frenzied efforts at ingratiation on the part of the male. What is interesting is that the help which the sea gives, as it does in so many ways towards making life easier and simpler, by providing a medium in which the ejected sex cells can mix and fertilize, does not prevent the evolution of a more individualized and intimate behaviour: the broadcast, the hit-or-miss principle, is soon discarded for something better. With some creatures the sperms are actually placed by the male within the uterus of the female—the nautilus, for instance, that remaining representative you will remember of the paleozoic cephalopods, grows a special arm for the purpose and allows it to break off or remain and atrophy when it has done its job. (That sort of thing however should not be thought of in anthropomorphic terms, lest it becomes too horrifying.) Other sea creatures by touch and caress induce the female to lay her eggs into the water and at once match the process by the emission of their sperms. This though mechanically only a careful synchronization is in terms of feeling and emotion so obviously something very much more.

Let us now for a while turn our attention to sex and sexual behaviour in insects and those other creatures that are equally descended from the early sea arthropods, the *arachnids*. To most people, educated or otherwise, spiders and scorpions are not arachnids but insects, which mistake is a perpetual annoyance to those with consciously correct and scientific minds who do not fail to point out that insects have six legs and three sections to their body and not eight and (usually) two. But spiders and their kind, with their size-restricting inefficiency of respiration and their lack of an internal skeleton, are so like to insects that the popular view is in many ways more reasônable than the scientific one—and indeed could speciation have been from the beginning by behaviour and not form the present differentiations that the orthodox are so careful to insist upon might never have existed. Nevertheless we can segregate some difference of behaviour in the arachnids, by saying simply that it is on the whole even more ferocious, more inhuman, more cold-blooded and more shocking to the tender-minded and intolerable to the sentimental than that of the insects proper. The reason for this may be that the arachnids are all carnivorous: they do not develop any social instincts; they are lone hunters; they are voracious.

The female spider has the universal and unenviable reputation of devouring her husband. But as Dr. Maurice Burton has pointed out in his book *Animal Courtship*, that is much too sweeping a generalization. The fact remains nevertheless that this is a frequent habit of theirs. Can we explain it or condone it? As for the latter the correct answer is of course that we should not try. But it does not seem quite so horrifying or at least so madly or unreasonably horrifying if we seek to explain it in terms of competing instinctive urges or drives. One urge perpetually with the waiting female is: 'Something alive?—let me grab and eat it.' The other is: 'A male, let me mate!' The male's job is to establish his identity and intentions, and to make himself scarce again when his intentions have been translated into action and his maleness has become of secondary importance—and to do both with the utmost dispatch. To effect the first he will for instance very tentatively tug on the strands of the web, ready for flight if his message is misinterpreted; or he will wave his long legs in a ritualistic manner that will be recognized. Or he will bear gifts—and with no guile in his heart as had the Danaeans, As for the second necessity, to save his life: the plain truth is that in many instances he does not even seem to try. This is courtship at its utterly grimmest: the drive, the paramount urge, is the purely impersonal one of the propagation of the species, the continuance not of the individual but of life.

Sex is almost as much a merciless tyranny among the insects as amongst the arachnids, though not so universally. Insect behaviour in all aspects is so varied, and often so apparently reasonless and entirely incomprehensible that generalizations are dangerous—except the universal one, that the insect is not a mind-directed but an instinct-ridden creature. There is beauty in the married life of dung beetles co-operating with their nauseating little pillules; but on the other hand some beetles also eat their husbands. There seems romantic beauty in the summons of the moth obeyed by the males from all quarters converging unerringly to the unseen bride. But Fabre in his experiments found two things: that the males, worn out by their quest, died within a few days whether consummated or not; that the males would as lief try to mate with a scent-impregnated match-box as with the female moth. Then there is that most romantic episode of all in the recorded annals of insects, the nuptial flight of the bee which ends in death. The nuptial flight of the ant ends too in a manner sufficiently drastic, by the queen tearing off her no longer needed wings. But this is not a noble act of self-sacrifice; the more we know of insects the easier it is to see that to speak so is quite unjustifiable anthropomorphism. All such acts are in fact but workaday parts of the job, steps in the life-cycle as impersonal, or almost as impersonal one must imagine, as the beat of the hammer on the balance wheel of a clock.

It may often be, as we have suggested, that the individual instinct of self-preservation is so weak in face of the overriding racial instinct for fecundity that the male spider, scorpion, beetle, fly, does not really try very hard to get away from its cannibal wife. There is the little empid fly who at his best kills an even smaller fly, bundles it up in its own silk thread and presents it. While the lady is excitedly undoing the lovely parcel and eating the contents the male does his mating and makes his getaway; he is even cleverer sometimes and manages with a second-rate and entirely inedible gift. So the story goes. What is more likely is that here exists one more of those strange and unexpected symbolisms of animal behaviour and that the gift is the necessary stimulus to sexual response, both as it were spiritually by the very fact of the gift and also very practically by the supply of the protein meal. That on those occasions when the real meal is lacking the male fly has been cunning or lazy is rather incredible. More probably his behaviour pattern has merely become a little mixed and confused. When the female praying mantis begins to browse off the front portion of her mate while the hind portion is still fertilizing her she is not in the least, we may be sure, suffering even a twinge of conscience or guilt. From the purely practical view: why not? She needs the protein meal in the job ahead of giving birth to the next generation; it is all indeed a labour-saving device most admirably arranged.

Yet, of course, all that is from our human point of view utterly revolting—and the human point of view is after all what matters to us humans. The practice of sex in the insects and their like, though it may show streaks of beauty, though it may even at times, in such habits as gift bearing, disconcertingly mirror our own, has taken as its main course a path not towards but away from all that we look upon as the taming and the sublimation of sex.

It is mind that is finally going to sublimate sex, or rather, to stick to the physical plane, it is brain—the sort of intelligent, self-conscious, sensitive brain that the vertebrates evolved. Fish, the first vertebrates, have not very much brain, but at least they made the big brain possible by providing a protective box for it, the skull. Fish in their various behaviours portray a queer mixture of most primitive instinct and most refined sensitivity and we shall do well to look at some of their habits before turning in the next chapter to the culminating brain.

First of all there are the examples of a complete slavery to the reproductive urge. Very many kinds of fish congregate in masses in order to spawn, subject perhaps to that ectocrine 'releaser' poured into the sea to set the process going. But some are subject to an earlier and a spectacular and still quite inexplicable urge : the salmon must leave the sea for the river, the eel must leave the river for the sea. Their stories are familiar but none the less amazing. Both suffer their endocrine glands to alter their appearance; then both, victims of a ruthlessly imperative urge, suffer every risk and danger in order to reach their rendezvous. There these madly ardent males exhaust themselves in pouring forth a mass of sex cells that, were all to propagate and live, would soon populate the seas solid with eels and salmon. The salmon is described as returning down the river spent, haggard, emaciated, lucky if he survives. The eel, quite simply, does not survive.

This is the completely promiscuous way of breeding, the wasteful and inefficient way that succeeds only by the ruthlessness of its drive. Nature here is a harridan : there is no joy in this. Turn for contrast to the little stickleback of our own rivers and estuaries.

When the Spring comes the male, having put on a rich coat for the occasion, forms with his mouth a hollow or pit in the sandy bottom—in fact a nest. He collects pieces of water plant and arranges them in a sort of tunnel to his nest. He patrols his territory, proud and bright. When another male appears he chases him off. When a female appears he displays as aggressively—until recognition makes him change his conduct. He dances before her, he leads the way to the nest, he motions her in, and she obeys. He butts the base of her tail with his snout. At length she lays her eggs and goes. He then releases his sperms ; and follows this, as is well known, by guarding the eggs continually, and guarding too the young fish that will even enter his mouth for protection from any imminent danger.

There are other small freshwater fish that have habits that are much the same, the tropical ciclids for instance. And the thing that increasingly strikes one in reading about them is the likeness of their behaviour to that of birds. There is the same territory patrolling, the same bright colours, aggressive display, dance and sign language to evoke the desired responses from the female. All that can be added is that perhaps the whole business is, even more than in the birds, an unalterable behaviour pattern and an automatic and instinctive drive to which the creature is slave. Stop the cycle artificially and it can never go on from where it left off. The vivid colour of the male fishes will even vary with their success in claiming a territory and chasing off their rivals.

Parental care is shown in quite a number of fish, and curiously it is often the male who takes the burden. Some little fish of the tidal shoreline actually wrap their bodies round the fertilized eggs;

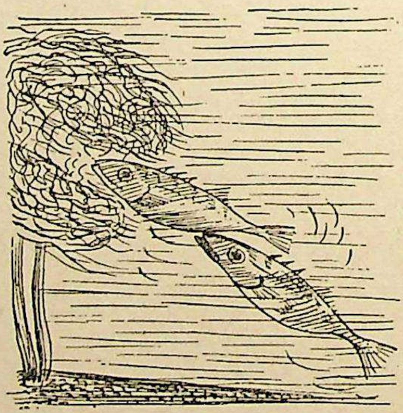

FIG. 52. He ushers her in

another kind forms a floating nest from mucous and then with his mouth sticks the fertilized eggs on to the under side. The male of the sea-horse—that curious little fish with the curly tail, always swimming upright—possesses a pouch in which the eggs are hatched—and as for its relation the pipe-fish, the eggs are actually laid within the male, nourished within the male and given birth by the male with all the appearance of exhaustion at parturition usually thought to be only ever experienced by the female sex.

Then there are hermaphrodite fish, and fish with whom the fertilization is fully internal within the female and the young are born alive. It is as if every experiment had been made before the next great evolutionary step was taken and vertebrate life emerged on to the land. Certainly one thing is significant: the fish who build nests or in other ways care for their young are mostly river fish, or estuarine, or of the tidal shores, in fact where the movements of the waters makes some sort of protection almost a necessity. Whatever was the actual line of ascent from fish to amphibian, in whatever order through the millions of years all these habits and behaviours developed, whether parallel or in sequence, it does at least seem likely that they came, once again, as response to the challenge of environment.

One other thing seems apparent: that it is not out of place to speak of joy in the fish's way of mating. Fighting fish of Siam embrace each other in their watery courting dance, the male scorpion fish darts with excitedly open mouth at the female and half engulfs her head—perhaps not joy, that, for the female—and the stickleback is observed to tremble with emotion.

At any rate he trembles. No one can prove it is with emotion; and even if it is it may well be very primitive emotion, hardly savoured in the small brain. Nevertheless brain, the protected vertebrate brain, is there; and the elaborate and vivid behaviour is there too: to deny the beginnings of emotion would be unjustified.

CHAPTER XVIII

Brain and the Use Of It

IS the brain the seat of the emotions? Through most of history people have thought otherwise. The Greeks used the word *phren*, which can be translated literally as 'midriff' and poetically as 'breast'; the Bible speaks of 'the bowels of compassion'; and songs have always bewailed the pangs of the heart.

Nevertheless it is the brain that sends, or rather sends on, the messages that make the heart to beat faster and the midriff to flutter. The statement that we are constituted not of body and mind, but of body-mind, may be hackneyed, but it is very true: one entity with two aspects, interdependent and never wholly separable. Here indeed arises the misapprehension, which after all was a very natural one. For we do not *feel* our brain, as we do our heart or our bowels. Examination of the brain has in fact never been easy: no stethoscope will make its pulsings audible, nor will any movement be visible to the most penetrating X-ray. It is only quite recently that anyone has come to know very much about the brain.

What we have first to realize now is the number and variety of functions the brain performs. It both enables us to use our senses and registers the findings of those senses. It controls our movements with subtle skill and balance and precision. It stores our memories; and then—consciously or unconsciously, by will or at the dictate of some whiff of scent, or momentary touch, or fleeting sound—it brings back for us those memories. It keeps our basic and lowliest body mechanics working—and enables us to perform the miracle of speech. It generates electricity (infinitesimally)—and registers our inspirations and gives birth to our dreams. Certainly if such an instrument can be evolved then the power of evolution is unbounded.

The beginning of the story of the evolution of brain is, very definitely, life's invention of the nerve, that incredible adaptation and specialization of a cell that can draw itself out to a thread a hundred thousand times its thickness and increase its embryonic powers of transmission of an impulse by a degree beyond calculation. Indeed we ought really to go back further, to the fact that one-celled life has the property of 'irritability' and the powers of response to stimuli, possessions not at all explicable in mechanical terms. Consider again that specimen of one-celled life, *paramecium* or the 'little animal that is shaped like a slipper'. That creature is perhaps a survivor, virtually unchanged, from the vast experiments of one-celled life which, we suggested in an earlier chapter, must have been tried out in the archaeozoic seas. The slipper animalcule can row itself by cilia, can back away from the unpleasantness and strike out on another course. Is that brain? Of course it is not: paramecium cannot see, cannot feel, cannot think, is not as we understand it conscious at all. The single-celled animal is an example of both how far *sensitivity* extends back in life and of how long the road is before we reach the reasoning, remembering, thinking brain.

We must avoid as far as possible recapitulation of the first chapters: we will look back, but from a different angle. Nerves, it will be remembered, appear first in the form of an unco-ordinated network: there is no central control. A jelly-fish has one main reflex action, a repeated message, 'Push! push! push!' so that it shall flap its amorphous body upwards towards the surface of the sea, when presumably some reaction to increased light, some *tropism* so-called, tells the automaton to stop, so that it may slowly float downwards and catch what food it may on the way back. This it will absorb as mindlessly, with no more conscious satisfaction one must assume, than an amoeba. It will sting with material venom but with no more hate than a nettle.

The star-fish, spiny-skinned echinoderm, will do a little better. Cut off one of the five rays, put it on its back, and it will right itself by twisting over at the tip as successfully as if it were connected with the rest. Put a whole star-fish on its back and whichever limb finds a purchase first will by means of the central ring of nerves inhibit the rest, whereas if the ring be cut all five limbs will war against each other. Here—in the uncastrated creature—is the beginning of co-ordinated control.

Next the worm, the creature with a front end that leads the way. Some distant cousin, says W. Grey Walter in that book, *The Living Brain*, from which we have already quoted, 'some distant cousin of jellyfish or starfish, spawned with a deformity of its nerve net, steered its way a little more safely through the crowded primordial sea'. It had, says the author—using the language of the modern engineer, and with intention since there are striking resemblances between live brain and electronic brain—it had invented 'feed-back', an elementary system of control whereby the forward end of the organism can gather information and feed it back internally for the guidance of its motor nerve centres. A *swelling* of nerves round the end that matters has evolved; as the importance of that end increases, as it becomes more recognizably head, with mouth, feelers and eyes, so gradually the nerve swelling, the ganglion, becomes more recognizably brain.

And here as a digression though an important one we may take up and dispose, rather summarily, of the brain of the arthropods and in particular the insect. The standard pattern of the worm—and it was the invention of segments that the arthropod took over and developed, you will remember—is for there to run back from the embryo brain a double chord of nerve with twin swellings on either side for each segment. And curiously these swellings have more power to act as something greater than mere substations of control than one would imagine. Put a worm in a T-shaped tube where one path of the cross-bar leads to an electric shock, and in time the docile creature will learn which way it is better to turn. Remove the brain from its head and those twin sector-swellings will of their own manage to perform the same trick of learning. Apparently it does not need much in the way of a nerve-knot to furnish the basic functions of a brain. And what is significant is that the arthropods, whilst retaining in various modified forms the segmented type of body, have also retained the segmented type of brain: the insect's head-brain one might call no more than *primus inter pares* with its other nerve knots, co-ordinator and inhibitor in chief but little more. *That* system can apparently produce wonderful phenomena of instinct and racial memory-pattern, but it cannot give—it is not physically large enough to give—the reasoning, conscious brain that has developed in the mammals.

We may now return to the main line that did in fact lead to man. It is a story of increasingly efficient sense organs developing hand-in-hand with better 'feed-back' and better brain to deal with the messages and to command the body to act upon them. The lancelet leads to the fish: notochord leads to the backbone proper, protecting the great artery of nerves, as multiple-stranded as any telephone cable under our streets, and to the skull, that necessary box for the new organ.

But what we are really seeking to understand is the development of something much more wonderful than the mere efficient machine for interpreting material environment and controlling the body-machine. All that, impressive though it is, is not *intelligence* ; it is not ability to learn and remember and profit by experience; it is not consciousness as we understand consciousness, consciousness of space-and-time and not merely space, of cause-and-effect and not merely effect. And the only way for us to understand the growth of this sort of intelligence is to get down to a little pretty stiff going in the description of the brain itself.

The vertebrate brain is divided into three parts, called with commendable simplicity hind brain, mid brain and fore brain and running up in that order from the spinal cord—or rather, in all but man who alone carries his backbone vertically, running forward from the spinal cord. And the real point about the hind and mid brain from an evolutionary point of view is that they gradually lose their relative importance. They are the controllers of the bodily functions; and, speaking broadly, the further back in the brain the more unconscious is the process—our breathing for instance. As brain evolves, the hind and mid brain either continue these duties but lose their relative importance or else push the more conscious controls, the receiving and the response to the sense-stimuli, to the better and more delicately equipped front of the brain. One exception to this rather wide generalization ought to be made in passing. It is surprising what an amount of brain is needed to control *balance*, bodily balance that is, and the finer play of the muscles. From the reptile upwards, both in mammal and bird, part of the hind brain does increase in size and elaboration. That is the *cerebellum*, so-called because in man at any rate it has remarkably the appearance of 'a miniature brain'. Let us be clear however—the cerebellum, however marvellous it may be, is not the seat of our intelligence or our thinking powers. It is the part incidentally that is the most quickly, not to say the most spectacularly, affected by the body's imbibing of alcohol.

That can bring us back to the fish and the main line of the brain's evolution—not the alcoholic afterthought but the fact that the more you are able to think the more you will have a fore brain to think with. What is significant about the fish's fore brain is not only that he has one at all but also that what he has of one is taken up largely with one function only. You remember that curious fact that your nasal passages must be damp, that smell is a sense taken over and elaborated from the life of the waters ? The great function of the fish's fore brain, the first job which is promoted to this new part that is going to be so subtle and successful is—smell.

Smell and the interpretation of smell is in fact going to exercise the fore brain for quite a while in the course of the brain's evolution. But leave that idea for the moment. The more important point is that the fore brain *thinks* about smells—smells first of all that is to say and less earthbound sense impressions later in the story. The fore brain's function is to co-ordinate and analyse. Later it will be able to co-ordinate and analyse several different kinds of sense impression at the same time.

In physical terms this means two new things : the splitting of the fore brain into two 'hemispheres' each side of the head—why this should be nobody knows—and secondly the great increase in the miraculous spongy stuff—do not be put off by its material description !—called 'grey matter'. Grey matter appears increasingly in layers and thin sheets near to the surface of the brain, to elaborate finally in man, as is well known, into such convolutions as will give a maximum surface within the confining box of the skull.

We must now know a little more about the evolution of the fore brain than that it blossoms out into ever greater area of rind and convolutions of grey matter. New terms must be absorbed—they will appear repeatedly in almost any book on the brain. They are : 'olfactory lobe', 'thalamus', 'corpus striatum', and 'pallium'.

There is no trouble about the meaning of the first of these, which is obvious : the place where smell-messages are received. The diagrams on the opposite page show how this persists but loses its importance with the Primates (as it does, as we should expect, with the birds). The thalamus, lying at the back and on the floor of the fore brain, is concerned with our powers to retain an even blood temperature ; it is also concerned, more importantly, with trial-and-error kind of learning and the ability to acquire a 'conditioned reflex'—something more about this later. The corpus striatum, in front of the thalamus in either hemisphere, is the part of the brain which *par excellence* the bird has developed. There, somehow, there can be stored the bird's substitute for a high order of intelligence : stereotyped but most complicated and subtle behaviour-patterns.

The pallium is the rest of the fore brain, in man in fact the cerebral cortex. It is divided into archipallium and neopallium—the

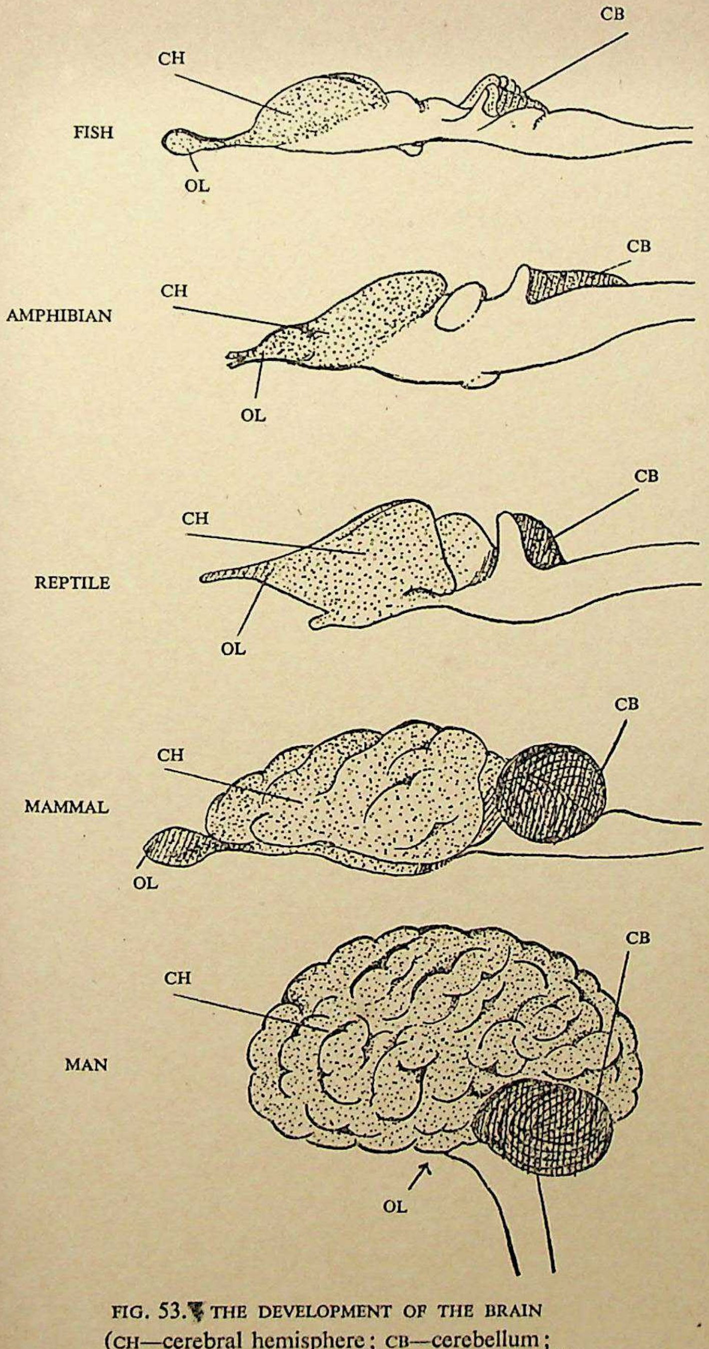
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FIG. 53. THE DEVELOPMENT OF THE BRAIN
(CH—cerebral hemisphere; CB—cerebellum;
OL—olfactory lobe.) [After *The Science of Life*]

ancient and the new—and the more primitive the animal the more 'archi' is the fore brain, and vice versa. Archipallium is concerned very largely with sorting and interpreting taste and smell; and neopallium is concerned with interpreting sight in particular and, one might say, everything else in general, however complicated and however subtle. That is as far as we need to go on the physical and material plane. The accompanying drawings, though they cannot illustrate all the terms mentioned, do give quite dramatically an idea of the evolutionary changes, with the olfactory lobes finally shrinking and the fore brain as it were blowing itself out to become with man a tight-packed convoluted mushroom of a thing overshadowing everything else. It is the outward and visible sign at least to the anatomist of the all-important invisible, intangible growth of greater powers of learning and sensibility and emotion and consciousness—in a word, of mind.

No one—and this though obvious needs to be said—can declare with certainty how any other creature thinks or feels, still less how any extinct creature thought or felt. Nevertheless we can be guided at least by analogy with our own consciousness, and also quite considerably by the physical size and shape and make-up of the brain: even an empty fossil brain-case can tell us a good deal.

The sad thing about the extinct amphibians and reptiles is that they do not seem to have been very much more intelligent creatures than the fish that preceded them. It might be true to say that their energy expended itself in proliferating in such fantastic variety—a sort of racial madness, a touch of that sun whose direct rays were a new experience for them. For millions of years life continued successfully with virtually no thinking brain: if that long summer had never changed life would presumably be still content without such a troublesome invention. One development is significant: that of the saurian second brain at its spinal base. This was a great help towards conquering the double disadvantage of enormous size and a lack of thermostasis. The rate of nerve messages declines with the temperature, and without this deputy-control at the back the giant would have been in a poor way indeed: as Grey Walters has said, anyone could have bitten off his tail and literally got away with it. But the creature's reactions must have been wholly automatic and its awareness of them perhaps hardly more than our own consciousness of breathing.

Thermostasis, controlled warm-bloodedness, is indeed the necessary release for improvement in brain. It is not only, apparently, that nerve messages can be quick and constant in speed, it is the fact that constancy—the opposite of wild variations of feverish excitement and cold lethargy—is the condition which the brain itself must enjoy for its better and more subtle functioning. This is becoming more and more clear as the workings of the brain are studied electronically. The million tiny impulses that are the physical attribute of our slightest thought shimmer across our brain as a puff of wind sends a network of ripples over the surface of a calm lake—and as has been significantly pointed out the lake must be calm for the ripples to show.

Thus the warm-blooded mammal had created within himself an environment in which could develop a better brain, in which could in fact slowly develop an utterly new invention, the big and intelligent brain, something quite different from the instinct-storing nerve-knots of the insect or even the small clay-tablet brain of the bird. Yet the mammal was not very quick in doing this. It looked at first as if when the land was cleared for him he was going to do no more than copy his predecessors and burst forth into a crop of loutish *dinotheria*, terrible beasts as big and brainless as the *dinosaurs* or terrible reptiles. Very nearly, perhaps, he took the wrong turning—and his end might have been even swifter. For the mammal, it may be said, has given hostages to fortune not by the number of its children but by the fewness. If survival amidst all the dangers of life was not going to be achieved by the bludgeoning method of numbers it would have to be achieved some other way.

The other way was in one word, *teachability*. The salvation of the mammals—the second batch of mammals that survived—was in essence a brain that could really learn: the brain, so the biologists like to point out with a flourish but with some considerable reason, took over from the sexual organs the job of ensuring the perpetuation of the race.

We must now look more closely at this important business of learning.

The insects we can dismiss summarily: they do not learn, they have other methods which if they fail ludicrously enough at times—you remember the wasp feeding the front end of a grub with its back end—work well enough on the whole. As for the birds, most people have read in Lorenz's book *King Solomon's Ring* of the gosling who followed him about as it would a mother because it was he whom the bird had seen at the crucially impressive moment of hatching. This is called 'imprinting' and is another aspect of the malleability and subsequent unalterableness of the bird brain—rather as if an electric circuit had been created that would continue for ever and could be let out to function whenever a particular switch is operated. Even the teaching of a young bird to fly is not really teaching: it is encouragement to use a faculty that is already there, a 'running in' of a mechanism stiff through not having yet been used—though that is an inadequate simile, since this is not a mechanism but an inborn pattern, a racial memory, waiting to be perfected by use and thoughtful practice.

In many ways the young mammal when he begins to learn is doing the same thing. The newborn colt when it struggles to its feet cannot be 'trying' to stand, in the way of making a conscious effort to learn a job. There must be an inborn urge to use those remarkable but ungainly legs. But when it begins to use them, then the new brain comes into its own—in telling the muscles what to do and, more important, in telling the muscles what not to do when a false step is made. Soon the colt will cease to stumble; it will be able to gallop, with its mother, away from danger in the prairie, towards the proffered lump of sugar in the farmer's field.

The colt gambols, the lamb skips, the kitten pounces, the puppy bites, the young monkey grabs. In one word, they *play*.

Not the play, this, of the birds or some mammals or most men, communal play, nuptial play; but the intent play of the young creature teaching itself how to use its skill, expanding its brain. Expanding too, surely, its imagination: no one can say that the kitten does not indulge in make-believe.

Then the mammalian parent takes over. Partly of course that is again no more than encouragement. But it is often a pretty active and thoughtful encouragement—and whether we like it or not it is the beasts of prey that take this business the farthest. The field naturalist has told us much of this sort of thing: the father, returning from the hunt, depositing a half-dead victim for the practice of the youngster's inexperienced claws; the father or mother taking the cubs on their own first hunt. Then mere instinct is not entirely absent; it will be the sudden whiff of the scent that sets the young behaving as they have never fully behaved before. But practice makes perfect.

The final stage—the final stage except for man—is for the child to watch and copy: conscious imitation. No one I imagine has ever observed a colt or even a puppy watching and copying its mother. For this there seems to be needed eye and hand: hand that is the inquisitive, the skilful organ beyond all others, and eye that is not only keen but has behind it a brain having as it were swept clear for itself a whole area from the tyranny of the response to smell. That can of course only mean one class of animal, the higher primates. Watch, for instance, how often a young monkey's eyes are raised from its hands to look up at its mother. And chimpanzees can learn to dress themselves in human clothes and to eat at table with decorum. True the first is not a very useful accomplishment for them and the second is subject to terrible lapses. But the *teachability* is most certainly there.

But let us leave the teaching of the young, for the learning powers of the adult.

Scientists are fond of putting animals into mazes or other similarly difficult situations. The subsequent reactions of the animals may give little clue to what most people would call their 'cleverness', for by that they usually mean the responsiveness to the words, signs and moods of human beings, which responsiveness is of course wonderfully and hearteningly subtle. What the experiments do test, and what they are intended to test, is simple basic intelligence. How *flexible* is an animal's behaviour, how far can it 'reason things out'?

On that count the insect again scores no marks whatever, the insect considered as an individual that is: his behaviour is not *designed* to be flexible. The bird does not do much better: put food the other side of wire netting and the hen, slave to its immediate reaction, will continue to peck wildly for it, only discovering the way round, if at all, by pure chance. Mammals do much better, dogs succeeding, most people will be glad to hear, much better than for instance rats. Indeed dogs can be trained to do the most elaborately 'clever' things to get at their food.

And yet move a box, the latch of which the dog has most ingeniously learnt to open, through no more than a right angle and the poor beast will be flummoxed. Animals are so amazingly clever; so amazingly stupid.

And why do they fail? What in terms of brain activity does all this mean?

It means in essence carrying trial and error to a complicated pitch of perfection by the exercise of memory. It means building up a habit by aid of that memory—and then if necessary when the circumstances change, rapidly *un*building it again. It means, in scientific language, and particularly, making use of conditioned reflexes.

Pavlov and his conditioned reflexes is a subject of which most people are rather tired. But we cannot for that reason dismiss it out of hand. Briefly Pavlov measured with great exactness and variety the ways in which a dog's simple reflex to the appearance of food—to whit, slobbering—could be 'conditioned' so that the dog recognized an earlier symbol, or even combination of symbols, to mean that food was on the way. Not only so but there was the 'de-conditioning' of symbols, and the very subtle choosing between two symbols nearly alike: one shade of grey for instance meant 'dinner to come', another shade did not.

Now that is in essence these four things: choosing; rejecting (all the sights or sounds that is to say that had no particular significance); remembering; inhibiting (the sign that is to say that has been changed and lost its significance). And these are the basic processes of thinking; one may almost say, they are thinking. The dog can really do marvels in this way—until it comes to comparison with the human being, when his marvels become by comparison crude and elementary. The dog learns to react not only to the smell of cats but actually—wonder upon wonders!—to the name of 'cats': *we* learn to understand the whole of speech.

And that is really the best way to illustrate and bring home to ourselves the last great leap of the evolution of the brain, from mammal to man. In man archipallium, largely smell-brain, has given pride of place to neopallium; and large parts of that complicated involuted cortex are given over to the direction and understanding of speech.

Speech means *ideas*, a tremendous extension of the capacity to conceive abstractions. Man alone seems able to perform the final trick, of being able to consider anything in the abstract—to remember, *and* associate, *and* consider, *and* compare. Learning by trial and error has in fact given place to learning by reasoning: in Man a course of action can be gone over in the imagination and rejected if found wanting, all without ever having had to be put into action with its possible dire results if the choice was a wrong one.

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One final word about the apes. We have rather left them out in coming to the end of the story. For that *is* the end of the story of the story of the evolution of the brain: Man, who can talk. *Homo Sapiens* was not a very good title to invent for him; he is not often, not outstandingly, wise. But he is outstandingly intelligent, he has achieved a consciousness and an understanding, which sets him apart from the rest of life. The Biblical phrase is the more right: 'as gods, knowing good and evil'.

The anthropoid ape is by no means as a god. Nor is he for that matter our direct ancestor. There has been considerable observation and writing about his conduct, particularly that of the chimpanzee, the most intelligent and least specialized of the apes. It is both revealing and pathetic.

'So far, and no farther' is outstandingly their sad motto. Much has been made of one outstanding chimpanzee's outstanding achievement. It saw a banana hanging out of reach; it saw packing-cases and a pole lying about; it piled one packing-case on another, took the pole, and knocked off the banana. Here is indeed the beginnings of reasoned thought, of 'putting two and two together'. But no more, that was the limit. Nor is there so much publicized some other findings of Professor Koehler about his apes. They had virtually no mechanical sense, so that their crate-piling was crazily inefficient; they never learnt that a ladder will only not fall if leant against a wall from a little distance; they could never see how to unwind a rope turned two or three times round a beam.

And apes can never be taught to talk. For all their cleverness, all their bicycle riding, cigarette smoking, banana knocking, they never begin to talk. They are often afraid, and often puzzled. There is a barrier; and they, it seems certain, will never pass it, because a few million years ago their ancestors took a different path, and in evolution there is no turning back. . . .

CHAPTER XIX

The Growth of Love

AT the end of the last chapter but one we left the fish trembling with emotion, or what it seemed justifiable to call emotion; at the end of the last chapter we left the anthropoid apes trembling on the brink of conceptual and ideological thought and yet denied of the powers of speech, unable to take the plunge. Now we have to consider the developing emotional behaviour of the creatures that lie along this vertebrate line of life.

One word of warning before we proceed. This evolutionary story does lead to man. But let that be incidental; let lessons, analogies, morals be eschewed and left to the anthropologists and sociologists who sometimes seem to wander where any biologist would fear to tread even though it be the latter's legitimate ground: the Old Man of the Tribe did not necessarily ever exist because the Old Gorilla apparently does.

It will be well on this occasion to state the end that we expect to reach and then to see whether we do in fact reach it. All categories are artificial but that does not say that they are unuseful. We have suggested a general picture of life as having streamed into three main lakes or reservoirs each with its very peculiar characteristics: the insects, the birds, the mammals. The first has not produced brain as we understand it, has not produced individuality as we understand it; but it has produced a social life. The birds, we say, have not produced very noticeably a social life but they have produced individuality and emotional intensity. Mammals are not devoid of emotional intensity nor certainly of individuality. And they *have*, as their final success, produced outstandingly a social life, the civilization of Homo Sapiens. That is the end of the story. How did it happen? Is it a continuous story at all? And was it because of brain and because of sex, or in spite of brain and in spite of sex? Those are the questions we need to answer.

The amphibians are a poor lot nowadays, a harmless and likeable but pathetic remnant.

Male newts flame into colour in the breeding season and, returning to the water, dance before and beside the female. There is a swishing of the tail as there is often with fish and it has been suggested that there lies a relic of inherited behaviour that has continued like a vestigial and now useless organ. Fishes no doubt feel any beatings of the water by means of their sensitive 'lateral line', but there is little trace of this in the newt; even the lizards, one stage further along the evolutionary line, seem to observe this same motion, when they are dancing and displaying on land. Male newts emit their sperms in capsules and upon these the female if in the mood will press her body. But she may well, it is reported, thus absorb the capsule of another male, a mere spectator, who himself has been stimulated to sympathetic action by the lively display of the first. This looks more like survival of the most cunning than the fittest, the early story of the tricking of a mute inglorious Esau. In plain fact, it is probably no more than an intimation that mating in the amphibians—assuming, that is, that the same sort of thing happened with the primitive giant flounderers of the Paleozoic Era—has not yet become very much of a personal matter.

Frogs croak. No one has called that beautiful; but it may have been the first sound, the first sound made by a living creature, other than the faint whir of slow and primitive insect wings, that the silent lands had heard. The sea is vast and most creatures in it either anchor themselves in groves or disport themselves in shoals. The wideness of the land however must surely have invited some sort of adventurous wandering. And yet the aim and end of all life would remain, to pass itself on before it died; and for that the male must *find* its partner. The voice and the mating call arrive.

Indeed not only that but there arrives the chorus. No one could imagine that frogs croaking in unison through the night are all calling for a mate. It is a habit surely foreshadowing the behaviour of birds: the mating excitement becoming a mutual excitement, one can almost call it a social excitement. That in fact is what we have need to remember at this stage of the story: the birds have not yet broken off from the main stem, and amphibians and reptiles often seem more like embryo birds than embryo mammals. In one aspect the amphibians—before we leave them—are almost reminiscent of insects and arachnids, though no doubt the likeness is superficial. Their eyes simply do not seem to register anything that does not move. A frog is said to starve in front of some dead creature that were it but alive would be seized upon and stuffed down the wide mouth with the four stubby fingers. The same is true of a mate. The female frog who wants to become a mother will do well to move a little in front of the male—though whether that leads on to all the coyness and chasing of the mammal, not to say the human, it would be rather more than rash to say. It may; though it is a long call from a frog to Amarylis in the shade.

Snakes are silent, except for a hiss; they find their mate by a quite remarkable sensitivity to scent left by the trail of the female. Sliding over each other they then perform long preliminaries of caress and touch that can only appeal to us humans as something endearing and akin to our own behaviour.

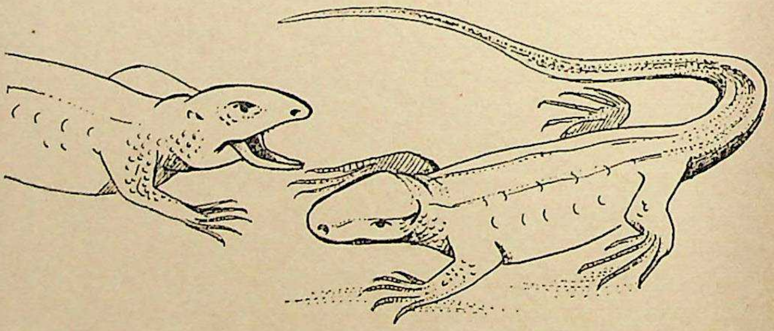

FIG. 54. Lizards courting

But again the courting customs of reptiles are most prophetic of birds. Lizards have territories and display before their rivals, and fight a fight that usually breaks off before much damage is done. They also keep their mouths shut until the crucial moment and then produce a startling effect by suddenly opening a most highly coloured one. Birds do that too.

It is the *immobility* of reptiles that is impressive. That is the overwhelming impression one gets from a tour of any Reptile House at a Zoo: immobility enlivened by rare but quick and sudden movement. Reptiles have none of the restlessness, nerviness, twitchiness, fidgetiness of ourselves or the mammals. Partly perhaps this is a protection against enemies—when, that is to say, nothing with better or more discerning sight existed in the world. But more it must be a result of their lesser brains, their slower nervous systems, the coldness of their blood. The reptiles are also a sad remnant of a former glory and the glory itself was so strange and must have reflected a kind of life so utterly dissimilar that we are not likely to find in it much that has bearing on our own. Remember too that the reptile is still an egg-laying creature, and an egg-layer that mostly leaves the sun to do the hatching. The word mother has little significance if the children are seldom seen and even less often recognized. For that we must wait for fur and feather and warm blood.

If it is legitimate to talk of life's 'inventions' and to try to put them in order of importance the invention of fur and feather would undoubtedly be in the very first few. For so much depends on a constant body temperature, and fur and feather made this possible in a cold climate. There is also another significance: fur is *sensitive*. It can be extremely so, in the form of whiskers—and fish have those—but apart from this every hair of every mammal, ourselves included, has its nerve. It is not for nothing that we stroke our pets, that cats rub against us sensually, that monkeys and apes spend long pleasant hours grooming each other.

It is primarily the *internal* functioning of the mammal that really matters, the delicate and complicated functioning of the female. In terms of simpler life, not only does she produce an egg: she presents it at the right time for fertilization; she continues to carry it, her own body the cradle of the sea, the cache, the hide-out, the nest; she finally adjusts her body in this long series of nicely timed changes to feed the new life externally after she has fed it internally by her blood stream.

One result of this is that part at least of the elaborate pairing behaviour of other forms of life, of birds in particular, becomes for the mammal in plain fact unnecessary. Male and female in birds form what have been called—there is a pleasant aura about the phrase—'bond-forming habits', those mutual rituals of bowing and gift-bearing and the like that by means of the breed's curious pattern-sensitive mind ensures a smooth continuance of family life until the need for it has ended. The mammal father can, and in many instances does, perform his function and then depart. To that extent sociability amongst the mammals is not nearer to attainment but farther away.

Neither is the mammals' courting behaviour so pretty nor, except in the case of the primates, so colourful as the fishes, the reptiles, the birds. Smell comes back into the picture, strongly.

Now it is rather too easy to be repelled by a discussion of smell or to seek refuge in a sort of delicate facetiousness. The intelligent thing to say is that since our own sense of smell is comparatively poor there must be subtleties and beauties of mammalian courtship which we completely fail to realize. Nevertheless for a male to mark out a territory by the emission of pungent secretions or by-products from his body can hardly be called anything but more gross than to do so by flying to the topmost branch of a tree and pouring out a stream of song. We may perhaps remind ourselves that scents affect our own mind in the most urgent and primitive manner in their power to evoke memories and emotions, and that we have hardly the right to be revolted by these pungent animal scents since we use them for the base of the very ones that we manufacture and consider so much more civilized.

Deer possess musk glands below the eyes that come fully into action at the time of 'rutting'. So with other scents. That in fact is the next great point to be realized: that the mammals—the great majority of them—are tied to a cyclical recurrence of sex and of non-sex as are the birds and indeed most of the rest of life. The reproductive function, life's insistence upon continuance, is inescapably tyrannical; in many forms of sea life and with insects, as we have seen, it is often tyrannical to the point of death—when the body has produced the new bodies its usefulness is ended. The best we can say about the higher forms of life is that the tyranny is reduced but still there; if Atropos has become Aphrodite yet Aphrodite is something of a harridan. Animals have their times of 'rutting' or of 'heat'. Both are blunt, ugly words, and for once perhaps the scientists chose a better one: oestrus. Oistros means originally in Greek gadfly, and so its sting, and so metaphorically a goad, a mad desire, a vehement passion. The male becomes importunate, combative, sometimes ridiculous; the female, turned inwards as it were to the strange preparatory changes taking place within her body, becomes placid, at first indifferent, then complacent.

The deer is a little ridiculous, herding his harem, trotting and bellowing round the little group of females while they appear to take little notice, even more ridiculous when an unattached young male takes his opportunity when the superior buck is not looking, as apparently sometimes happens. There is something too of that curiously unheroic aspect that is so pronounced with the birds. The

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fight with those magnificent antlers is by no means often to the death, and in fact the antlers themselves do not appear to be very efficient offensive weapons. The sea lions and walruses seem more the slave of instinct than most mammals since the two sexes converge with an inexorable regularity on certain beaches for this herding of harems. Here too something of the territorial instinct seems to come into the guarding. But the fighting is real enough, as those who have seen Walt Disney's nature film will remember.

In all this there does not appear much sign of the increased brain and intelligence of the mammal. Perhaps we may regard these creatures, as we did in the earlier chapter, as specialists, their brains —and they certainly have them—gone more to controlling with magnificent skill and precision their long legs—and let us include the horse and the antelope here—or their seagoing tails and flippers.

Let us turn to the smaller, furrier animals. There is often an element of play in their courtship. Not a mere chasing, but a skipping and jumping, an exuberance. The mad March hare is notorious; and squirrels are said to rush round in large circular dances before they go off to pair. If we look on all propagation as excess energy, as we may, then here the energy manifests itself not in display as with birds, not in the growth of appendages that are as startling as they are otherwise useless, but rather in equally useless but also startling and thrilling action.

The little furry mammals also excel in mutual caressing. So do birds of course; but on the other hand one can hardly imagine frog or lizard doing it, and insects only seem to caress for the very utilitarian purpose of getting a free peptonized meal, while fish—with a few outstanding exceptions—get no further in cosiness and companionship than going about in shoals. We have come in fact, via the sensitivity of fur and feather, to the advantages, joys rather, of warm-bloodedness. The frog and the tortoise seek the warmth neither of their own mate nor their own mother but of the more impersonal mother earth. The big and ungainly and long-legged mammal is not entirely barred—it can lick, it can nuzzle. Nevertheless it is the small, neat, unspecialized animal that really has the advantage. It can, in a word, cuddle—which is not an over-sentimental word to use since here, we may believe, we are indeed witnessing the birth of sentiment, or at least of something like it. Social life is more than a huddling together for warmth, a sensual licking of fur. But surely it can start that way and one cannot begin to love one's fellow beings if one cannot bear the feel of them.

Obviously the mother and young are very much in the reverse position from hating the feel of each other—and here at last we begin to leave sex and courting for the things that follow from it, emotions stung to less urgency and so less gross and more kindly.

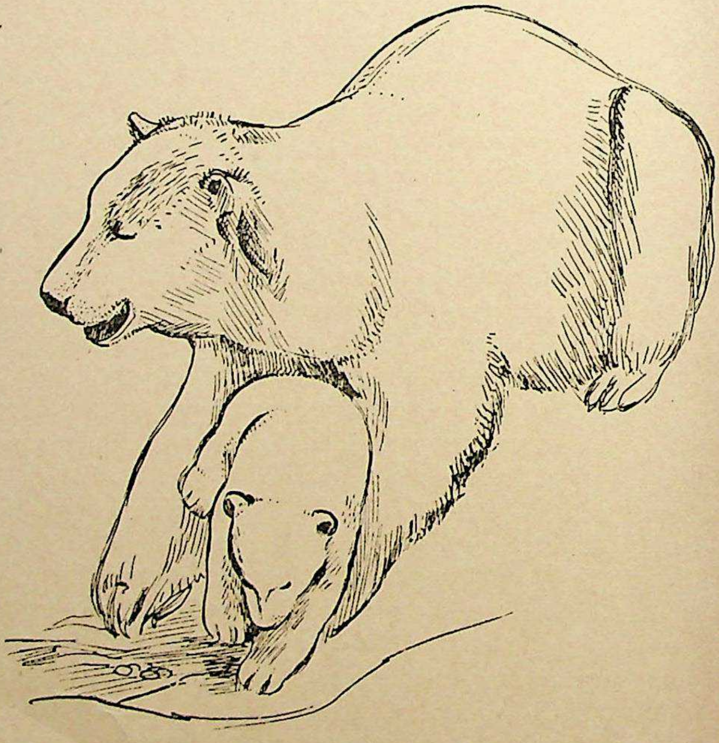

FIG. 55. The warmth of love

Put shortly, the mammal and the bird possess the *incentive* for love and companionship and family life—and with the mammal this is perhaps likely to endure longer for the purely negative reason that the young have only two dimensions and not three in which to wander away. . . .

And now, sadly, we suffer a regression, our optimistic course is checked. We come to the higher Primates, and we find their sex life not more admirable but on the whole most unequivocably less. What is the trouble?

Nothing incidentally is quite as tidy as we would like in this matter: generalities have to admit of some exception. Nevertheless as generalities they are good enough—and here is the first of them. With monkeys, apes and men a new and significant situation arises: they are mostly freed from the cycle of oestrus and anoestrus, of being first most highly sexed and then of being virtually not sexed at all. And it is a very considerable emancipation, for there is surely something rather degrading in being so at the mercy of the turn of the seasons and of becoming of a sudden virtually a different person. With the higher Primates the urge and the drive let up; they spread and become more, a little more, diffuse.

The result of prime importance is that the male—and this is the second wide generalization—ceases to become after every recurring bout of passion a lone, or at the least an uninterested, creature. The attraction of the female is there all the while—he will stay around.

The potential advantages of that are obvious: a sane and equable social life, not subject to storms of frenzy; a true and permanent family life. The potential dangers are obvious too: sex merely becomes a harridan not recurring but present all the time.

The social life of baboons has been studied extensively. From the observer's point of view they have the advantage of living in groups, often quite large groups, and of not disappearing out of sight into trees. From what is known of them, the behaviour of the monkeys on the one hand and the anthropoid apes on the other does not differ radically from that of the baboons.

And the behaviour of baboons is not edifying. The unit of the group seems usually to be a male with a jealously guarded harem of from one to six wives. Trailing around with these is often an unattached male—who, like the young stag, sometimes takes his opportunity. Life, besides being the usual perpetual search for food, is a more or less perpetual arena for the frequently recurring assuaging of the sexual appetite. On the surface at least there is mostly a calm or at the worst a truce between the family units of the group. But at times and for no apparent reason a fight starts over possession of a female and then a wave of savagery overtakes the whole colony—and the poor female is fought over until in all probability she dies.

Nor has the baboon wholly emancipated itself from the tyranny of sexual cycles, nor certainly from the grossness of sexual display. With the Primate's victory of sight over smell colour has assumed greater importance: at the time of menstruation the female is not only more desirous and more willing, she shows it by the brightness of her sexual skin—which she displays.

And yet. There is a better side to the picture. A social life has been established. Children are brought up, tended and—with some casualness admittedly—taught. Mostly there is peace—long hours of lazy, happy, sensual grooming. If there is seldom monogamy there is little or no absolute promiscuity; if there is at times raving jealousy, this at least presupposes love however unspiritual, individual choice and individual preference. And since these occasional savage storms do not break up the society there must be during the times of peace much mutual tolerance, and respect for law and hierarchy even if it be the law of present possession and the hierarchy of might.

So much for baboons, and there is indeed not so very much more to say without wandering into the domains of anthropology.

Let it be remembered that neither present monkeys nor present apes are in our own direct line of ancestry: it is at least possible that in course of time they have become degraded—they show if nothing else how much farther man has progressed in creating a social life. We asked at the beginning of this chapter whether mankind created his society because of or in spite of sex. The answer is surely, both. The mammal, with his lack of a wholly or largely instinctive brain—a possession that must make life so much easier—had obviously to be freed first from the tyrannical, character-changing cycle of *oestrus* before he could live in amity with his neighbour. Yet that very freeing made it in some ways the more difficult for him since it was in danger of creating a permanent tyranny of sex in place of a recurring one. However, without jealousy there is not love, without combativeness there is not individual choosing or faithfulness, and without propinquity and warmth there is not compassion or companionship.

The bigger brain enhances the emotions, brings them to the surface of consciousness. The mammal admittedly is not self-conscious, he cannot reason. But undoubtedly he is capable of the emotions as we know them: fear, hate, joy, love, compassion, altruism—not often those last perhaps but sometimes, as the

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animal lover and the field worker, not the laboratory worker, will tell you.

For the rest, the real command by the brain of the instincts and the bodily urges and emotions has to wait until the appearance of man—or rather, for the beginnings of such a command the world had to wait for man.

> Move upward, working out the beast,
> And let the ape and tiger die!

exhorted Tennyson. The idea, though old-fashioned, is surely sound, though nowadays we do not look with quite so complacent an eye. In some ways the beasts, with their less complicated, less tortuously inhibited reactions, are superior and more admirable than ourselves. Brain, on top of a beast's emotions and instincts, was a fearful gift. A knowledge of good and evil is obviously not an unmixed blessing: perhaps we can say, even as thoroughgoing evolutionists, that it did indeed entail a Fall.

Insect, bird, mammal and man largely populate this earth and each has evolved a way of life. It is easy to be an insect, it is one would imagine pleasant to be a bird; to be a mammal is to be dangerously sensitive; to be an ape largely a tragedy, and to be a man—indeed what? It is best put perhaps in terms of potentials—extremes of potentials either way.

From the time of the tree shrew, that small unspecialized mammal that ran in the branches in a younger world when the dragons were about; from those times some seventy million years ago, these three, brain, the passionate warmth of the blood, and motherhood with the young at its breast, have somehow, and with a spectacular spurt at the end of the run, produced our species.

CHAPTER XX

Success At Any Price

THIS chapter was promised as a corrective to complacency. If we are to understand Evolution we must first at least get our facts right: Evolution is not an automatic advance that leads to the triumphant entry of Man. It has indeed performed that miracle; it has also successfully populated the earth with intelligent mammals, successful insects and emotionally satisfied birds, not to mention the teeming fishes and a host of not very noticeable miscellanea. But that is not all—there is a darker view. Like Hamlet's mother, we must, for the good of our souls, 'look upon this picture and on this'.

Life is ubiquitous. Life *presses*. It exacts existence from this Earth; the highest of its aims seems often to be no more than the greatest number of separate lives, the greatest number of separate pieces of existence. And Nature does not in the least seem to worry about the means so long as it achieves its end.

Take parasites.

But, first, clear your mind of some prejudices and preconceptions—do not be too disdainful, too superior or too willing to be disgusted! Remember that all forms of life, except the majority of green plants, live on other forms of life. If you are not a parasite you are a predator; and if you admire the lion and despise the liver fluke—which it is surely right to do, for it is an understatement to say that one is considerably more heroic than the other—nevertheless you should remember that both live on other animals and cause a good deal of suffering in the process. Indeed one should perhaps go further and remind oneself that the parasite by no means always kills—though there is nothing heroic in that either: it is not in the interest of the parasite to kill, any more than it was to the interest of Hansel and Gretel to pull down their cake house about their ears.

Nor is there much point in our becoming sad or indignant when we learn of the lower forms of life that become parasitic. Always there is life within life. Our blood cells lead an existence of their own; by no means are all the bacteria in our body harmful. Protozoa, elaborate and active entities of single-celled life, teem within the body of the termite and so enable the creature to exist upon a diet of wood—and both are well served. But when the virus, the microbe, the protozoan are harmful instead of helpful within the bigger body it is yet no great shift of a way of living for the lesser creation, even though it may mean the difference between life and death for the greater.

In a perfect world one would imagine that there would always be mutual help and never the reverse. In fact, the first—called scientifically symbiosis or living-together—seems no more likely to happen than the second, parasitism.

Even it may happen that symbiosis has led to parasitism: it is as if the balance were too delicate to maintain, too good to last—just as it is a truism that two sets of people can seldom get on together indefinitely in the same house, or, perhaps a nearer parallel, that beneficiary often grows to turn against benefactor. There is a tiny flatworm that stains the sands of parts of the coast of Brittany a noticeable green. That is because the larva has swallowed green algae which thrive on its waste products by aid of light through its wellnigh transparent body. But also the young worm thrives on the algae, growing its vegetables as it were in itself rather than its garden. That is a well-balanced symbiosis. But when the worms have mated and are growing old things change and the balance is destroyed. Already the worm has given up eating externally and has lost its mouth—a fatal mistake! Now it absorbs its internal algae too fast, and the end is tragedy as complete as any sixteenth-century dramatist could wish for, with everyone dead. But perhaps that is no more than another example of nature's lack of care for the individual life once it has served its purpose of perpetuating the species.

The greatest significance of parasitism is something quite different. It is something apparent also in other forms of life that help to build up this blacker side of Nature's picture. The life history of another worm—the worms are great parasites—that in fact of the 'unheroic' liver fluke, will give us what we are after.

We will consider the story of this ingenious creature, or rather series of creatures, as impersonally and with as little disgust as possible.

The liver fluke is hermaphrodite but prefers to cross-fertilize—within the liver of the sheep. It is about an inch long. A terrific number of microscopic eggs are laid. They are extruded into the outer world in the sheep's dung. If on dry ground, that is the end;

if on wet, it is the beginning of the next stage. A larva, two-hundredth the size of its parents, is hatched. With cilia it swims about eagerly. It is searching—consciously one cannot assume, though it is a matter of life and death—for a pond snail, a particular kind of pond snail. If it succeeds it bores within the snail, becomes little more than a long hollow bag and then, itself now adult, gives birth to yet a third creature, intermediate in size, wormlike and about a twenty-fifth of an inch long. There may be several generations of these, all living on and within the snail.

Then in the Autumn a change: the snail is perhaps becoming outworn. A fourth creature is born, a little smaller, round-headed. It feels the urge to escape, and it does so. Again a swimming about in damp places—even up the dew-wet blades of grass. There it encysts itself in secreted slime—and waits for the luck of being eaten by a sheep. Once more the sheep is the host, the parasite grows and feeds on its liver: the cycle is complete.

Now that is all almost incredible. It is, say the authors of *The Science of Life*, 'as if the offspring of men were mice and the offspring of mice were men'. It is also as if life had thought out the most idiotically complicated and hazardous process possible and had determined to make it work. And it has made it work. The species liver fluke continues. That is to say, one in every million possible lives—or half a million or five million or ten million, who cares?—continues.

The ingenuity of adaptation is, as ingenuity, wonderful—admirable, beautiful. But to what end? And at what expense!

Let us go a little higher up the scale of life. Sacculina is a crustacian. It starts life as a free-swimming larva. It goes through a moult and becomes in appearance more like a water flea and still swimming around as eagerly as does the second stage of the liver fluke. Finding one of its own Order of life, a crab, it hangs on and proceeds with the following drill: burrow inwards, roll around in the blood-stream—a cushy job that, as the soldier would say, with good eats—find your way into the body cavity, and finally settle down clamped firmly to the underside of the crab's abdomen. There Sacculina remains and feeds and lives—losing its limbs, sending out instead plant-like roots into all but the most vital parts of its host, and finally becoming a mass of eggs and sperms and so hermaphroditically fertilizing its own progeny.

This is much the same story over again: complicated change in order the better to stay alive without earning one's own living, atrophy of any organ that cannot be bent to that purpose. And here, with the much greater bodily efficiency and sensitivity of the crustacean as compared with the worm, the atrophy is all the more apparent.

Nature in fact by no means always steps onwards to greater sensitivity, greater control of the environment as a whole. This is not environment as a whole but environment in the very particular—and there is no control but a precarious hanging on. Indeed it is hardly right to talk of the parasite not earning a living: as an organic entity, as a piece of life, it works tremendously hard. There is a proverb that fits exactly, and which it is not foolish to apply: 'Lazy people take the most pains.'

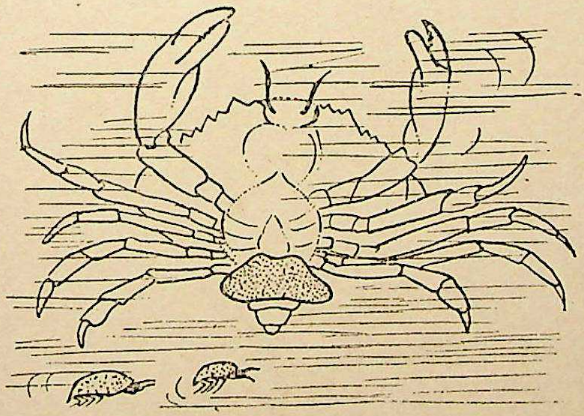

FIG. 56. Sacculina on the job

And there we can leave parasites, but not laziness or atrophy.

There are other crustaceans that are willing to sacrifice all their limbs and liveliness to settle down to an easy existence even though they do not fasten on to other life. The barnacle fastens on to ships and wooden piers, from there to waft food into itself in the lazy way of the paleozoic seas. But in its early life it is too a free-swimming creature, indeed to look at very like young sacculina. Then, something nearer our own vertebrate line, there are the tunicates or sea squirts, which sit on rocks looking like very embryo bagpipes, and pump water in and out of themselves. In their youth they are lively tadpole-creatures and they possess that precursor of the all-important backbone, the notochord. The bag or tunic is a later secretion—life chose for this creature an overcoat and the feeding habits of the polyp rather than the difficult job of becoming a fish. . . .

No discovered vertebrate, it is perhaps cheering to find, has become a true parasite. The hag fish goes some of the way, boring through into the body of his larger cousins. But he does not stay there, nor lose his mobility, moving in fact on to other game. And there is the curious and pathetic deep-sea fish, who becomes physically attached by his mouth to his larger wife, living on her life-stream so that he may fertilize her. That is parasitism of a somewhat different order, a sort of Matriarchy gone mad.

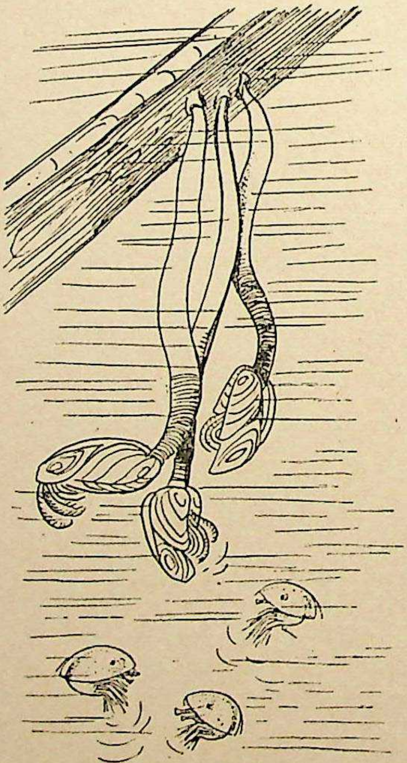

FIG. 57. Barnacle and young

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There is no *self-respect* in all this, that is the trouble—either on the part of the individual or of whatever it is that directs evolution. And to answer impatiently that one should not expect such a quality, or that we are unjustifiably imposing human values, is not to dismiss the subject—at least not satisfactorily to dismiss it.

Then there is sometimes a sort of dead-weight of tyranny about Evolution that creates as ugly a picture as does parasitism or atrophy. It has something in common with these forms of negation in that it is so much the opposite of all that can justify any easy, optimistic interpretation of life's progress.

H. G. Wells in his satire which he wrote in emulation of Voltaire's *Candide*, *Mr. Bletsworthy on Rampole Island*, populates the land upon which his unfortunate hero is shipwrecked with giant sloths. These creatures, he imagines, are still extant. And they are *hanging on*. They do not breed; but they do not die—for there is nothing to make them die. Their imposing, amazing size has made them tabu to and inviolate from the ignorant population; their utter slowness of living prevents them from becoming worn out. They are just a damned, lumbering nuisance—an incubus. And, so Wells points the moral: Evolution can work that way, life can work that way, if we do not wake up and do something about it.

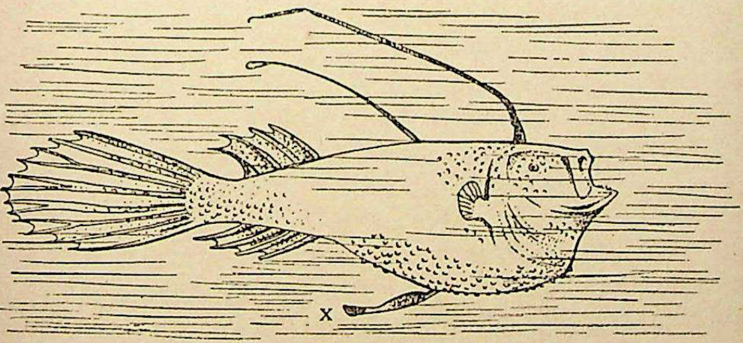

FIG. 58. The husband is marked with an x

Those sloths were fictitious. But they did exist; and it is true that in Patagonia they did in fact continue to exist long after the rest of that first Eocene rash of giant brutes had subsided into no more than amazing bones buried in slow accumulation of the Earth's crust. Something such as Wells envisaged could have happened.

It surely did happen, something like it, with the reptiles. The brainless giants stumped the earth while the tiny embryo mammals kept out of the way. And they did it for millions of years : what hope for any advance during those aeons could any intelligent being have seen ? Giantism seems almost to be a recurring theme in evolution : to subscribe for a moment to the Manichean way of thinking, one might imagine the forces of evil every now and then being allowed by a temporarily nodding God to try out the principle of brute force and bloody ignorance. But Manicheanism may be as much an Evolutionary heresy as a Christian. Be that as it may, there has even been discovered in China giant human teeth that date from somewhere about the time of Sinanthropus. We did not mention them in the earlier chapter because there are those who argue that giant teeth do not necessarily presuppose giant limbs and that therefore this particular find has no great significance. These people may be wrong however,* and it is at least possible that Man too tried out brawn rather than brain and size rather than sensitivity. We can relieve the gloom of this chapter by reflecting that in fact the experiment, if made, was *not* a success.

The true lesson is that evolutionary advance is obviously not automatic or inevitable. All that seems inevitable is that life seeks, at the expense at times and if necessary of everything else, to fit itself as well as possible to its environment.

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* Another find of these teeth was reported in 1956, and now a creature called *Gigantopithecus* is talked about.

CHAPTER XXI

This Is Heredity

WE come at last to the way in which Evolution works—not the 'mechanism' of it, because as has been already suggested, that is surely a wrong and misleading word to use, the essence of the whole affair being the very antithesis of mechanical. We have traced the history of life, what is believed, that is to say, to be its most likely history. Having reached the stage where brain took first place in importance, where feeling, sensitivity, consciousness, behaviour, are the attributes that matter, we took three separate courses to the three outstanding kinds of present-day life: the insects, where instinct seems to lord it over individuality; the birds, where 'emotion' and 'patterns in time' seemed the significant words; the mammals and man, where emotion seemed to be leavened—or, to take a dimmer view, bedevilled—by intelligence. Now we should be in a position to consider the 'How?' and the 'Why?' of Evolution.

To ask why may be little more than presumption. But at least we can consider why Evolution should have worked the way it has, or worked at all; what is the purpose behind it, or can we perceive purpose in it; finally what are we to believe about it. All that territory we shall explore in the last few chapters of this book, at times treading delicately lest we offend but not we hope altogether too timidly.

'How' brings us to Heredity and Genetics—difficult subjects.

Nevertheless it is not at all impossible to find a way through to a pretty clear understanding. What we need first is an open mind, the sloughing off of all prejudices, and probably the intentional forgetting of all the odd tags of knowledge that we possess, because the points that are liable to have remained stuck into our minds are very possibly not the significant ones, though they may well have been the most stimulating or irritating.

Mendelism for instance. What most people know is that there are factors of heredity that are 'dominant' and 'recessive'. That is the most memorable discovery that Mendel made; but it is not really the most fundamental.

The temptation to treat this subject historically must be resisted: that would take a book, not a chapter. But it will help to say first a little about this rather romantic and rather sad figure, the Abbé Mendel. Mendel had never seen the chromosomes, those infinitesimal strings, writhings and stirrings in the heart of the cell, that later laboratory workers were to stain and peer at through their high-power microscopes—at least it is not known that he ever saw them or appreciated their significance if he did. He worked the hard, slow experimental way, where results, one would imagine, are more memorable once they are achieved and where the temptation to make startling claims is perhaps in the nature of things more effectively curbed. He was born, the son of a Moravian peasant, in 1822; his parents scraped to give him a good education, and, having been apparently often half starved, he chose the profession of Augustinian priest primarily as one that relieved him of future anxiety on that score. He became a teacher and—significantly, like his contemporary and senior by one year, Fabre—a loved and brilliant teacher. He also worked in the garden of his monastery near Brünn, trying to introduce new colours and varieties in his flowers and becoming increasingly interested in hybridization. 'One who surveys the work done in this field,' he wrote later, 'will come to the conclusion that, among the numerous experiments, not one has been carried out comprehensively enough to determine the number of different forms under which the offspring of hybrids appear, or to arrange these forms with certainty according to their separate generations'—he knew, in fact, that he was doing pioneer work.

His findings were published in 1866 in the Proceedings of the Brünn Society for the Study of Natural Science. And they were virtually ignored, Darwin, for instance, remaining in ignorance of them, though had he but read and appreciated he might have been saved the invention of his hypothetical and later totally discredited 'gemmules' as the carriers of heredity. The findings remained in oblivion until rediscovered, more or less independently, by three botanists at the turn of the century; and Mendel, scientifically a very disappointed man, became Abbot of his monastery and increasingly involved in the business of his Office, with little time and one must imagine little heart for further patient experiments.

What Mendel discovered must become apparent as it arises in that which follows, an exposition of heredity as the vehicle of Evolution. All that needs to be appreciated initially is that someone working as it were from the outside and not within, working empirically and not theoretically, was able to enunciate laws of heredity and to speak with some certainty of the 'factors' that were apparent in those laws.

Now let us begin at the very beginning. This question needs asking: why should there be such a thing as heredity at all? If every kind, every species, of animal is held to be a separate creation, it would not be wholly ridiculous to imagine every life as a special creation. In other words, that a child should take after its parents is something not in the least inevitable but rather something that we should be able to recognize, however familiar it may be, as highly significant. *Life does copy itself.*

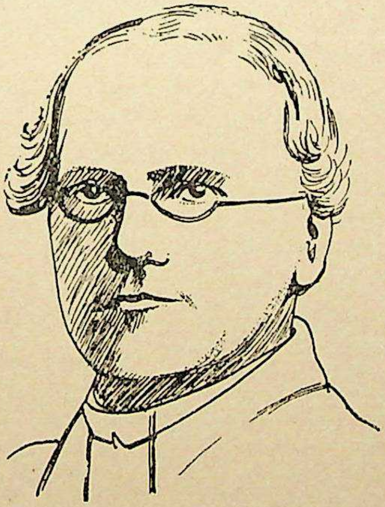

FIG. 59. The Abbé Mendel

From that we may well go to the other extreme. Why should there ever be any change? Why should not the child be an exact replica of its parents, or for that matter, remembering the womb, why should not the child be the exact replica of its mother? Again we are very familiar with the fact that it is not so. And that too is significant.

From that, then, a second dictum: *life copies itself, but not exactly.*

This also is what we might expect. Our children are like us but not all *that* like: 'I am sure,' we say of some delightfully unexpected little trait, 'I am sure I don't know where he gets it from!' Then it is the same, we appreciate, with the animals that we breed.

But how does it all happen; what is the carrier, the fairly faithful but slightly unpredictable carrier, of heredity? Is it the blood? That has been the answer through most of man's existence, so much so in fact that it has become firmly and probably irremovably implanted into his language; and was there not the poor unhappy Nazi youth who preferred to die rather than receive a foreign infusion of the precious and magic liquid into his veins?

The true answer is that the hereditary principle is indeed in the blood, but also in every part and tissue of the body. Further, it is protected and inviolate, as safe from contamination, and as incapable of contamination, as the canary in its cage in a submarine has lack of influence over the sea. The hereditary principle is within the nucleus of the cell—within the nucleus of every cell of the body.

We come back, indeed, to the *chromosomes*, which we have hardly mentioned since the first chapter of this book. There it was the first drastic method of the continuance of life that we described, continuance by splitting. Now we have to learn that the same performance is gone through every time a multi-celled animal, ourselves included, goes through the process of forming new cells within its body, which it does all the time in the process of developing and keeping alive, the primitive method of propagation having become the normal method of growth.

And how ordered and careful and meticulous, we will remember, that process is! The rod-like chromosomes split themselves apart down their axes and so multiply themselves by two; then carefully and jealously they are ushered to each end of the cell that is about to divide, so that never a new cell shall be formed that does not possess its exact quota, a complete set, of the chromosomes.

When all this was discovered there was no proof as yet that the chromosomes did in fact carry the factors of heredity or were indeed anything to do with heredity. But already it was apparent that there was something tremendously significant and important about them. It was the contents and behaviour of the sex cells which made matters very much more plain.

To break off for a moment, and as a reminder: the sex cells are called gametes, 'marrying cells', the male being the small active sperm and the female being the passive and large ovum—large that is by comparison. When these two unite the result is called a zygote, the thing that is joined or 'yoked' together. Genetics abounds in technical terms and as far as possible we will try to avoid the use of any more of them.

Ova and sperms, then, the sex cells, were discovered to form and multiply themselves within the body in a way significantly different from that of any other cells. Instead of the chromosomes collecting together, splitting themselves, and being divided into two new flocks, in this instance they congregate into pairs, dance as it were round each other, mutually touching, and then retreat and pass half into one of the new cells and half into the other: the gamete has only *half* a complete set of chromosomes. This process is called very appropriately a 'reduction division'. Then later, when the union of the sperm and the ovum takes place, the two half sets combine in the zygote and the new life has a *complete* set of chromosomes, but half from the father cell and half from the mother.

And that of course is tremendously important. For if the chromosomes carry the factors of heredity then this is exactly what one would expect to happen—indeed something like it *had* to happen to avoid an impossible situation where the so carefully hoarded chromosomes increase by geometrical progression at every sexual union until their containing nucleus presumably bursts. The hypothesis that here in fact has been discovered the factors of heredity becomes a very reasonable one—and has in fact been since strengthened into a certainty.

Now let us examine the implications of all this.

The first is that heredity is not in the least a matter of the blood; it is a matter of the sex cells.

The second is that, since we know in plain fact that life does not copy itself each time exactly, there must be something in the chromosomes that possesses considerable variety. Otherwise the fact of inheriting one set of chromosomes from the mother and one from the father would give no more than a series of children at each successive birth that were certainly an amalgam of their parents but were all nevertheless exactly alike—a good method of birth control by boredom perhaps but with little else to recommend it.

Of course nothing of the sort happens. And there are two separate reasons for this.

The first is that the half set of chromosomes that gets shepherded into any newly formed sex cell is not the same as the set that has been left behind. Though the original full set of chromosomes is in a series of pairs, making this halving process possible, yet the partners of each pair are—in significant ways which we shall explain anon —*not* the same. And since it is purely a matter of chance which one of a pair gets itself included, and as there are a lot of chromosomes —in Man forty-six[1]—there are already produced large possibilities of variation.

The second major cause of variety in heredity is a curious one. It seems like accident or inefficiency and as if nature were taking advantage of this laxity for its own ends. When in the 'reduction division' of the sex cell the chromosomes pair up before being shepherded half this way and half that they do more than dance round each other with a little haphazard twisting and touching. Where they twist they appear to break at the point of touching and to move apart again, having swopped over above and below the break.

Now both these happenings would have no effect if the pairing chromosomes were the same as each other. But as we have said they are not. They may have affinities, they may have been just the same once; but each has at some time or other suffered change. *Their genes have mutated.*

There with brutal suddenness are two new terms, or at least new for this chapter. First genes, which will bring us back to Mendelism.

Scientists—particularly under T. H. Morgan in the U.S.A.—have made innumerable patient genetic experiments with *Drosophila*, the fruitfly, which has the advantage of breeding quickly and showing curiously enlarged chromosomes in some of its cells. In observing the behaviour of these chromosomes and of the characteristics of the ensuing new life scientists have been led to certain unavoidable conclusions. What these come to, simplified, is that it is not the chromosomes that govern characterististics but what is in the chromosomes, or rather what is on them. And that is the thing which in the science of genetics has been christened with the beautifully fundamental name, 'genes', after the Greek word *genea*, which means birth, race, descent, breed. They are, these genes, say the scientists (and as we have quoted before), 'arranged along the chromosomes like beads along a wire'.

Now, at once, two things must be made very clear about the genes. The first is that no one has been able to see a gene or segregate a gene. The accent is on '*like* beads on a wire'; indeed it may be nearer the mark to say as we do of the happenings within the atom, '*as if* they were beads on a wire'. The second point is that however real and material the gene may be—and it is not here suggested that they are not real, the calculation being that they are about the size of ten protein molecules—it must never be imagined that there is in that gene something material that is going to blossom out into the blue pigment of an eye, shall we say, or a particularly fine or a particularly stunted wing. Genes are governors, potentials, determinants—no more and no less.

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[1] Latest count.

They are indeed, so we must believe, the 'factors' of which Mendel spoke.

Mendel worked first with ordinary garden peas and then later with other flowers; and from what we have learnt of the oneness of life and in particular the similarity throughout both the animal and vegetable kingdoms of cellular basis and sexual process it will not surprise us to know that others later worked on animal life and obtained the same results. Mendel found that though characteristics may either apparently mix or even disappear entirely in one generation they will reappear pure, entire and unsullied in a later generation. They pass *through*, unaffected and unmixed. Effect a cross from a white-flowered and a red-flowered 'Four o'Clock' plant and the offspring will have pink flowers. But breed from these and there will be for every two pink-flowered plants one red-flowered and one white-flowered; nor, however long you breed will you ever get rid of the reds or whites. Pink in fact is not the result of something mixed as liquids mix; heredity is not—as Darwin could only imagine—'blended', it is 'particulate'.

Or take the more spectacular complete disappearance of a characteristic in the first generation. Mendel crossed wrinkled pea seeds with unwrinkled: result, disappearance of the wrinkled in the next generation. But grow a third generation from these seeds, and the wrinkled will reappear, in the proportion of one in four—and it can be demonstrated that of the other three one is pure unwrinkled and the other two have the wrinkled characteristic as it were latent within them.

This last is the simplest exposition of his famous law of 'dominants and recessives', for which he is best known. Nevertheless, as we said, what is the most superficially startling in his

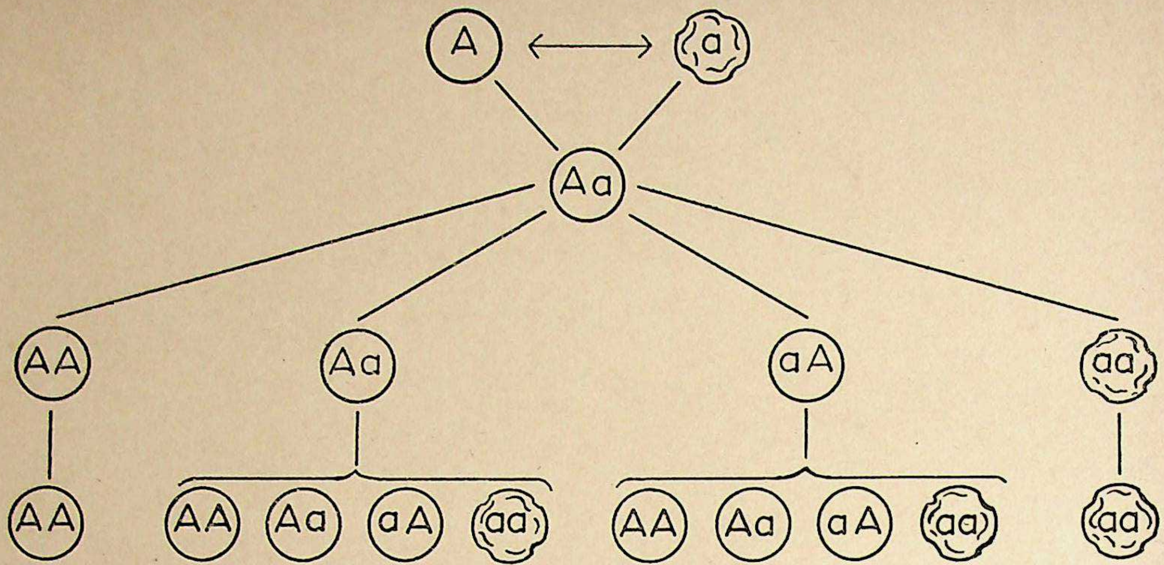
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FIG. 60. THE CROSSING OF THE ROUND AND WRINKLED PEA

The two middle peas of the third generation, though in appearance round, carry hidden in their chromosome outfits the recessive genes of the wrinkled characteristic findings is not the most important. The fundamental point is that hereditary characteristics are not things that get watered down to extinction; they are on the other hand inviolate and persistent—they crop up again.

And that surely, it can now be realized, ties up marvellously with what the later laboratory scientist has discovered: that the determinants of heredity lie—again, inviolate, persistent—within the nucleus of the cell, to be copied and continued in the cells of the life of the next generation. Indeed a way of looking at the whole matter, and a fruitful way, is to say that the things that really matter in heredity, that have the fundamental continuity, are the marrying cells, the *gametes*, forcing through the hereditary characteristics and in the process as it were merely 'throwing off' a body, the zygote, that grows up into no more than an ephemeral representative of the species, blossoming forth and then dying.

We come finally to the second of the two new terms, the fact that the genes 'mutate'.

To mutate means to change, and scientists are here giving an ordinary word a special and technical meaning. We have all heard of 'mutations'. They are the changes that are now known to occur in the genes of the chromosomes. There is nothing new in this so far: it is quite obvious that there must be changes—we come back to our basic proposition, that life copies itself but not exactly. What is important is that scientists have at last traced these changes that must be occurring somewhere, and found them within the nucleus of the cell. What is equally important is that they seem to occur not gradually and continuously but (rather like the definite 'packets' of the quantum theory in nuclear physics) suddenly, unpredictably and by definite steps. The step is the mutation: suddenly something happens, and the next generation is different.

Let us be clear about this and not jump to any fantastic conclusions. In all forms of life mutations are happening and have been happening though never frequently. *They* are the things that have caused the partners in a pair of chromosomes to become different; and that is so because—so far as is known—every change or mutation within a gene of a chromosome is a permanent change, and, whether dominant or recessive, does not disappear. Darwin had never heard of mutations nor had Mendel—they only occasionally bedevilled his experiments—and the discovery of mutations has a profound bearing on evolutionary theory. Here at last is discovered the raw material of evolutionary change.

But mutations do not work miracles. It cannot be said categorically that they are the sole material of evolutionary change. And there is a great deal that is not yet known about them.

What would be particularly helpful to know is what makes them happen. Unfortunately our ignorance here, though not complete, is profound. Hidden away in the cell nucleus, the gene could be expected to respond only to something rather drastic. Mustard gas was tried—why mustard gas I do not know—and it did have some apparent effect. X-rays were tried and gamma rays from the atoms of the unstable elements, with considerable effect. Indeed that is the best answer so far: mutations are caused by the rays from the disintegration of the atom. Hence of course our worry over the effect of atom bombs. But the Earth is bombarded perpetually with the rays or particles—you can apparently call them which you like—from disintegrating atoms, in the form of sunshine and of cosmic rays which come from outer space. Fortunately the atmosphere protects life from their more drastic effects. Two interesting points arise from this however. Carry unprotesting fruitflies into the upper atmosphere and they do seem to produce more mutations in the next generation. The second is an intriguing theory: that the early amphibians and reptiles mutated as violently and fantastically as they did because they were somewhat new to these rays, filtered by atmosphere admittedly but not filtered by the waters of the sea.

This in fact must be the final footnote of this chapter, and not unfairly: how much is yet unknown about mutations and genes and how much of what is known seems not to fit into any comprehensible picture but to need some new discovery that will make things fall into place.

Here for instance is a list of odd things that genes are reported to do.

In Drosophilia a gene can:

Make the feet grow double.

Turn the body a tan colour and stop the creature's tendency to fly towards the light.

Change the eyes from red to white, and alter the pigmentation of the male testis or change the shape of the female spermatheca (sperm storage bag).

Scallop the edge of the wing, but kill in double doses.

In Man a gene can produce:

Free lobes to the ears.
A tendency to twins.
A white lock of hair.
Left-handedness.

That, to say the least, is tantalizing.

It has however perhaps one good effect: it should kill any crude idea the reader may still retain from potted scientific representations that the gene is something that contains within itself in any physical way the embryo as it were of an organ that will later develop, a red eye shall we say or a particularly lacey wing. The gene is a factor, a control, exerted—physically, chemically, and in some other way besides—on the slow and complicated growth of the embryo. It is a matter of time as well as space: a gene may speed up this or slow down that; it will work under the control of others, to set this process of growth going or to prevent that. Finally this should certainly be realized: the genes work on the embryo and on the production and continuance of the new life *within its environment*. If identical twins—which have the same chromosome outfit—have inherited a tendency to tuberculosis, they will not necessarily both contract it.

CHAPTER XXII

How Does Evolution Work?

IT will be well to begin by putting down what all that has so far been written justifies us in saying about Evolution. There are three things, I think.

The first is that Evolution is a fact. No, that is going too far; for a fact must be demonstrable, and organic evolution in the nature of things is not demonstrable to anything so ephemeral as a human being. Rather—to quote from a Catholic book*—Evolution is 'an eminently probable hypothesis'. The evidence, particularly the evidence of geology—we cannot, like Hugh Miller's quarrymen, go on calling fossil sea scorpions 'Seraphim'—is too overwhelming. We may go on quarrelling over the significance of Evolution and the methods of Evolution; but, and again to quote from this book, 'a biologist in possession of the data now available has no right, practically speaking, *not* to be an evolutionist, as long as he remains unable to explain the facts in any other way'. Only a self-deceiver can explain the facts in any other way. There *is*, demonstrably, a continuous story of life. Man included, the creatures that live and have lived in this world must be related and have a common origin. Life—when or how we do not know, whether diffusely or pin-pointedly, slowly or startlingly, we cannot now tell—came to this world in a most simple form and from that beginning has developed. To imagine that man or any other creature arrived on this earth fully formed is and must be, for good or ill, as incredible to an educated person in the middle of the twentieth century as is the myth that Athene sprang fully armed from the side of Zeus or that Aphrodite arose from the foam.

The second point about Organic Evolution that should be generally acceptable is this: there may be a continuing story but there is certainly not a single and continuing advance.

The truth—and this is the third point—is something less simple. Rather, life spreads out along a multitude of divergent paths, achieving elaboration as it goes but reaching very different goals.

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* *God, Man and the Universe*, published in 1954 by Burns Oates & Washbourne.

It may reach static equilibrium; it may reach extinction; it may reach the potentialities of further advance. Whether there is as it were a central core of progress, using the term ethically, is a philosophical problem and does not come into this argument.

But *how* did it happen: that is what we have now to attempt to discover. What is the tool that Nature has used?

There is no simple answer, at least not one that is universally accepted, even by those who are all equally happy to accept the 'eminently probable hypothesis' of Evolution. That is in fact the next point to be stressed: *we have reached controversial ground.* There is an orthodox answer to the question and an unorthodox answer—it would be fair to say, I think, an increasingly insistent unorthodox answer; it certainly would not be fair to leave it out. But there are dangers, particularly in that the second answer appeals more easily to the mystically minded or, some would say, the muddle-headed. We must therefore be careful. And yet, at the same time, we must be courageous, not merely sitting on the fence but grandly standing up on it and surveying the two sides however dizzy it may make us or tempted we may become to jump down on one side or the other. So attractive to some, so anger-making to others, the ancient and hoary head of Lamarckianism is about to raise itself.

We shall have to have a little history.

Jean Baptiste Pierre Antoine de Monet, Chevalier de Lamarck, born in Picardy in 1744 and dying in Paris in poverty in 1829, is really famous, or should be, not as the propounder of a disturbingly heretical explanation of the guiding principle of Evolution but more simply as a great biologist—he invented the term—and a pioneer of the very idea of Evolution. We need to enquire how that idea slowly arose and how it led first to Lamarck and then to Darwin.

Evolution, after all, is not a very natural idea to come by. Men's first interpretation, as soon that is to say as they had formed any conception of God's creativeness, must surely have been of a series of separate creations: animals are so patently varied and different. It has been said that the agriculturists tended to believe in God's hands moulding man and the animals from clay, from the good earth (the Bible version), while the hunters, more conscious of affinity with the animals they hunted, tended to think of themselves as related to and indeed descended from animals. Too much should not be made of that however, more top-heavy edifices having been built on totem and taboo than probably anything else in anthropology.

But when the enquiring mind arrives ideas will change. For such minds will recognize the *likenesses* between kinds of life. Aristotle, so outstanding that he became known simply as 'The Philosopher', might with better reason have been called 'The Naturalist'. Gazing patiently through the waters of the Mediterranean, observing, afterwards dissecting as he undoubtedly must have done, he found out for instance things about fishes that were not only not rediscovered but scornfully disbelieved until late in the nineteenth century A.D. Aristotle believed in an 'upward scale' of all life starting from the lifeless, through the plants, the sessile sea animals so like plants, and so on to animals with more and more 'capacity for motion', 'sensibility', 'vitality'. He also, as one might expect, went deeper than that. He gave to that word 'psyche', which firstly meant breath, the idea of 'breath of life' and so of soul, differentiating between vegetative, animal and 'rational' psyche. He was what we should now call a vitalist and not a

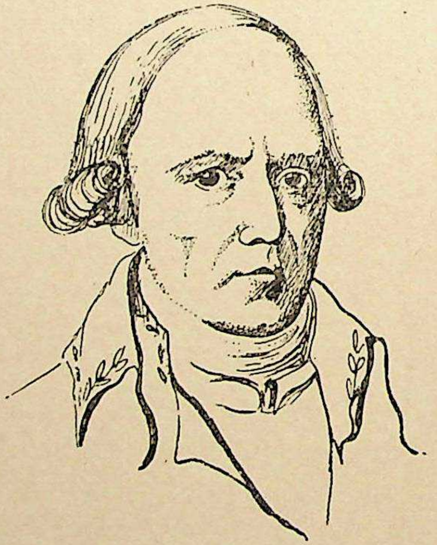

FIG. 61. Lamarck

materialist, believing that the essence of life is not something that can be defined in physical terms.

The Dark and the Middle Ages we can dismiss. It fed itself so far as Natural History was concerned on an uncritical acceptance of Aristotle and also of a less reliable Roman gentleman of the first century A.D., Pliny the Elder, who believed in cloven-footed ostriches and garland-presenting elephants and whose mind was unfortunately even more gullible than it was enquiring. For the rest, there was an unquestioning acceptance of the Book of Genesis and a habit of regarding the whole of animal creation as no more than a useful God-provided gift to man or a symbolic object lesson to him.

With the seventeenth century came what the Greeks had lacked, the microscope. The Naturalists were busy observing and classifying. Linnaeus, a Swede born in 1707, was the great classifier; and while, it seems, rather bewailing the Creator's lavishness which made the task so much more difficult, his care was above all to stress the need for classification if the scientist was to get anywhere at all. His pious and orthodox belief in the strict interpretation of the Bible story and the complete separateness and distinctiveness of species was a great help to him in his task.

But in order to segregate you have to compare: classification is based not only on differences but on likenesses, and likenesses turn one's thoughts to relationships. Aristotle's idea of 'upward scale' had not been entirely forgotten and was now due to return. The great Sir Thomas Browne, doctor, stylist, philosopher, mystic, wrote the following:

> 'There is in this universe a stair, a manifest scale, of creatures, rising not disorderly, or in confusion, but with a comely method and proportion.'

The modern biologist, reading the last phrase, might wish to add 'optimist' to Sir Thomas Browne's attributes. But there was the right idea.

Then came another idea. It was observed how difficult it was to systemize the animal and vegetable world into separate species and almost impossible to tell sometimes where one species ended and another began. Were species fixed? And if not, what changed them—was it a *natural* cause, or causes? In France, in Germany, in Italy, in England, Naturalists discussed these things, and apparently without heat and the dragging in of religion. In France the Comte de Buffon—'the eminent Buffoon' as Shaw relates his being called in a Dublin bookshop—spent a lifetime writing a popular *Histoire Naturelle*, wherein, critical of Linnaean classifications as artificial abstractions, he tried to consider Nature as a whole and to see significance in likenesses rather than difference. Species, he observed, altered in type from time to time, but retained marks of their previous type: perhaps some species were degenerate forms of others?

The first of the forty-four volumes of Buffon's tremendous work came out in 1749 and in that year Erasmus Darwin, grandfather of the great Charles, was eighteen years old. He tried to resolve the difficulties through which Buffon was groping. Towards the end of his life he wrote this:

> 'From their first rudiment . . . to the termination of their lives, all animals undergo perpetual transformations, which are in part produced by their own exertions in consequence of their desires and aversions, or of associations: and many of these acquired forms or propensities are transmitted to their progeny.'

Here was not only a recognition of Evolution but a suggestion as to how it might come about. And in fact it is in line with what is now known as Lamarckianism, the idea of transmission from one life to the next of characteristics acquired during that life, these characteristics having been produced by the habits of the animal concerned, the use or disuse of this or that organ or capability.

And there we must pause. For it is important to realize two things. One is that the idea, produced by the terrific impact of his books, that Charles Darwin practically invented Evolution is completely false. The other is that Lamarck was not the first believer in the heresy to which he has given his name. Indeed it would be true to say that before Charles Darwin enunciated his own theory something like the Lamarckian idea was common property and accepted if not without question at least without any feeling of guilt. To those who observed nature carefully and sympathetically it was, one might say, the conclusion at which they naturally arrived.

Now for the rival theories of Lamarck and Darwin.

Both stressed that the process of evolution of forms of life must have been a very gradual one demanding enormous stretches of time in which to function. But from there they parted.

Changing environment for any form of life, said Lamarck, created new needs for that form of life. New needs resulted in new habits and efforts to form those habits. This exercised certain organs and so affected and developed those organs:

> 'The frequent use of an organ, when confirmed by habit, leads to its development and endows it with a size and power that it does not possess in animals which exercise it less.'

It is in fact a matter of use and disuse. The mole almost loses his eyes because he has no use for them, the snake loses his legs which would be in the way in gliding. The giraffe, living in an arid climate, reaches up to browse even higher; and the giraffe has grown a long neck. For:

> '. . . every change that is wrought in an organ through a habit of frequently using it, is subsequently preserved by reproduction, if it is common to the individuals who unite together in fertilization for the propagation of their species.'

And how in fact, within the individual body, is this increase or betterment of the wanted organ brought about? It is not a matter of conscious will or of 'voluntary striving'—Lamarck has often been misrepresented there—but by means, he can only say, of a *sentiment interieur*, best translated perhaps as an 'internal power'.

How prove that these adapted and improved organs, these new characteristics acquired during a lifetime, were in fact passed on in their altered state to the new generation? Lamarck did not bother to prove it—his job, he seems to have felt, was to throw out ideas. Indeed that outlook of his may have been partly why no one took much notice of his theories during his lifetime; Lamarck was on occasions more than a little rash and irresponsible, he was, as they say, his own worst enemy. His giraffe idea, for instance, earned, and has continued to earn, him ridicule. The giraffe argument tends to become a sterile and unreal one. But we shall refer to it again; for, contrary to most people's belief, the last laugh does not seem to be with Darwin—in fact the last laugh can hardly said to have been yet.

Now Lamarck's theory is a remarkably neat and complete and in many ways satisfying one. It seems to tie up with common experience and common sense. Unfortunately there is one great flaw in it. No one as yet—and it has not been for want of trying, one scientist having even committed suicide on being convicted of faking his evidence—no one yet has managed to prove that acquired characteristics are ever inherited.

The curious thing about Charles Darwin is that quite often he too seems to subscribe to Lamarckian ideas; after all many people before him, including his grandfather Erasmus, had favoured such ideas. Charles Darwin talks often of the 'effects of use and disuse'. However, we will not allow that to confuse the issue: if Charles Darwin was sometimes equivocal those that have followed after him, the so-called Neo-Darwinians, with their increased knowledge of the mechanism of inheritance to sustain them, have had no doubts whatever that Lamarck was wrong. Darwin propounded a different theory to explain how Evolution came about; and that, uncomplicated by its original author's own doubts and occasional hedging, we will give.

The nineteenth century had been in existence nine years when Charles Darwin was born; and by the time he was ready to publish his *Origin of Species*—or rather, by the time he felt constrained to publish, for he would probably never have considered himself ready—the middle of the century had been reached. Though (spectacularly so!) a less religiously tolerant century than its predecessor, it was much more scientifically advanced. Darwin had behind him now the geologist Lyell, who had soundly rated all those who clung to miraculous interpretations of physical phenomena and in particular to a belief that nothing much had happened to the landscape since 'the Flood'; he had behind him Pasteur, who had proved that spontaneous generation whether of maggots out of decaying matter, honey bees out of a lion's mouth—'out of strength shall come forth sweetness'—or in fact anything from anything that was not its strict progenitor, was nonsense. Thirdly, Darwin was the ideological heir to Malthus, that particularly foreboding economist.

Darwin was very impressed with the Malthusian theory of the continual pressure of human population upon subsistence, the inescapable fact that, unless marriages produce consistently only no more than two offsprings, the rate of increase, being geometrical, is likely to outstrip disastrously any possible increase in food and sustenance, so that the only cures are a continual slaughter of the innocents or a conscious check by the population on the number of its children. *That*, said Darwin, applies equally to the animal kingdom—and the animal kingdom does not apply conscious checks on its fertility and the fertility is in any case a good deal more potent!

Darwin too, as is well known, went in his youth on a scientific expedition in an Admiralty ship, H.M.S. *Beagle*, visiting South America and rounding the Horn into the Pacific. That trip obviously made a tremendous impression on him and shaped the rest of his life. He was horrified by the miserable primitiveness of the Terra del Fuegan native, so much so that he felt that if anyone could accept being descended from such as those they could easily accept being descended from monkeys. More importantly he was impressed by the life of the Galapagos and other Islands.

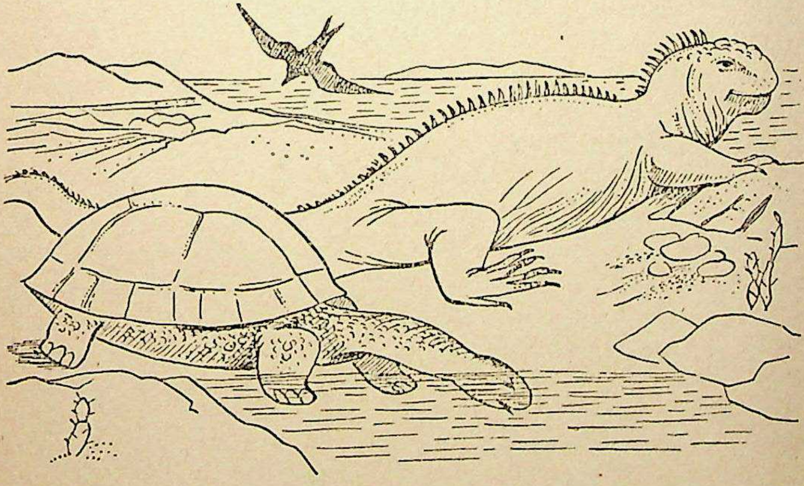

FIG. 62. Life on the Galapagos Islands

Rather as that other naturalist, Philip Gosse, found the shores of Britain, Darwin found these islands unspoiled, and in fact virtually undisturbed since the beginning of their existence. The variety of life on them he found amazing. But, much more than that, there were species existing that did not exist anywhere else, which indeed varied from island to island. If every species was a separate creation, why had God gone to such curious trouble?

When Darwin came home he studied the selective breeding of

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animals. This man-directed selection, he saw clearly, produced *modifications* in the offsprings, often in the end quite startling ones. It produced new varieties of life.

Was it possible, asked Darwin, 'that species had not been independently created, but had descended, like varieties, from other species'? It was obviously possible, if only there were some form of selection in nature parallel to the selection of the stockbreeder and the animal fancier. And that of course was where the Malthusian theory fitted in. There *was* such a selection. Indeed it was exactly what was happening all the time and there was no need to call it anything more than, simply, natural selection. Nature's most prolific habits in the matter of producing offsprings, coupled with the necessary ruthlessness of competition that had to go with it, produced a selection, a sieve we might say, as fine as any that any stockbreeder ever invented. However, what it was selected *for* was different: not some particular attribute like beefiness in an ox or yellowness in a canary, but, simply, the ability the better to find and thrive in the animal's surroundings. The selection was for the fittest, and the fittest survived. Life has the power, through heredity, of copying itself, though not exactly: Natural Selection seizes on these inexactitudes, these modifications, these slight variations, and proceeds gradually to breed into the stock what best fits the environment and to breed out of the stock what least fits the environment.

That was all. In some ways it was an even neater theory than Lamarck's. It was also very easy to understand. To some mentalities it was welcome, to some anathema—and so it has remained. It is true, too, that the increase of knowledge since Charles Darwin's time—and it has been considerable—has seemed for the most part to bear out and strengthen his theory. This however has not stifled the objections; it has made them only somewhat shift their ground.

In the next chapter we will proceed to consider the Darwinian theory as it stands today, to ask some of the awkward questions that need to be asked, and to see how well they can be answered.

CHAPTER XXIII

The Orthodox Answers

OBSERVATIONS and experiments that were patient, inspired, intelligent or plain childish, have been made in multitudes since Darwin's time—and even the silly ones have been useful in goading other people into impassioned thought. But, as has been said, the Darwinian theory remains, and more stark and unequivocal than when its author with considerable circumspection enunciated it. We may leave history now and concentrate on Darwinism rather than Darwin. Before leaving the great man however we should salute his greatness, lest frequent references to his lack of knowledge in some fields or to the criticisms that have been levelled against him, give the opposite impression. He was a very honest, very careful, very thoughtful, very courageous scientist.

A frequent and important criticism levelled against *The Origin of Species* is that in spite of its title, and whatever else it does, it does not explain satisfactorily the origin of a species.

The first thing to do here is to define a species. A species, it will be remembered, is most acceptably defined as a kind of animal or plant that while able to interbreed fully either cannot or in nature will not breed effectively with another kind, however closely the other kind may resemble it. ('Effectively' constitutes continued breeding: horse and ass are separate species because mule and hinny are sterile.)

The definition itself gives some clue to the Darwinian answer to the criticism. The rest of the clue lies in geography.

Life, as we have so often noticed, is both prolific and continually pressing to take its opportunities. As an example of this a species will continually press to extend over its environment—or to put it in more everyday language to wander over the land, or for that matter, if it can swim, drift, fly or be blown, across the sea and the air. It may not do this of course : it may be content to stay put, in which case it will fairly obviously stay put in form as well, and Evolution will be no more to it than it is to Evolution ; or it may try and fail, when its fate will probably be extinction. But take the successful species. It deploys. It wanders. Then those on the periphery may not want or may not be able to return. Something physical may intervene between part of the circumference and the centre, for the face of nature is always changing—at the most spectacular a new sea or a new mountain range may appear. No two environments are exactly similar, no single environment remains the same ; all the time life, as is its custom, is changing from generation to generation, little by little, in adaptation to that change. Cut off the two environments from each other and the two representatives of the original species, having ceased to interbreed by the simple process of being physically apart, will find if they ever do meet again (or if man in his experiments makes them meet again) that they cannot—or which has the same result, positively refuse to—interbreed. *A new species has been formed.*

That is what had happened on the islands that had so impressed Darwin. That is what must have happened, even more spectacularly, in the Continent of Australia.

Adventurous, or lucky, bats and birds found their way to the Galapagos Islands. There they found a new environment and incidentally a very favourable environment free from agile and predatory mammals. They not only flourished but they flourished differently on each island, responding through long ages with meticulous exactitude to the particular characteristics of their new homes. In Australia something different happened. What had been an extension of Asia became an island. At the time of the change this land supported as yet no placental mammals but only marsupials. Thereupon the newly isolated environment at one and the same time saved the marsupials from the deadly competition of their more intelligent and efficient successors, the placentals, and gave them the chance to respond to the opportunities it offered. This they did by producing types that parallel in a most revealing manner the evolution of their unknown cousins in the rest of the world, evolving predatory types, grazing types, tree-climbing types, faster moving types and a good many others. Why the fast moving types should have invented the jump rather than the gallop is anybody's guess. To the significance of this parallelism we shall refer again.

Before we leave this question of how new species must have been formed we can obtain a little clearer understanding of it from two modern branches of knowledge. One is animal behaviour and the other is genetics.

It is possible with creatures that have diverged in environment, and as a result in character, for there to be still no physical barrier to interbreeding should they re-meet but yet no actual interbreeding ever to take place. This is often because of that strange synchronization of behaviour patterns of which we learn in the life of birds. Nor, though they are there so paramount, are complicated and subtle courting habits confined solely to birds. In ourselves it sublimates itself into mutual attraction, and we cannot deny something of that in the higher mammals. If some increase in fastidiousness resulted in the black and the white races never again pairing we should be entitled to record them as different species and—particularly if they were also to remain in the environments in which they originated—they would as a result no doubt tend to diverge in characteristics even more.

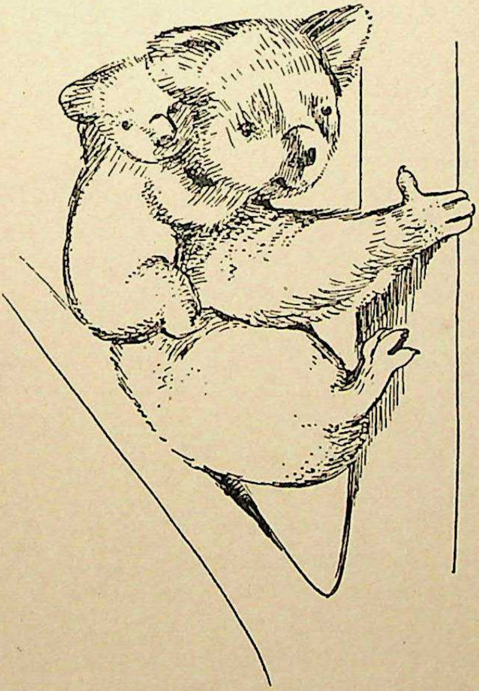

FIG. 63. Koala : tree-climbing marsupial

Genetics have shown us what happens in the zygote, the first cell of the new life, when ovum and sperm combine: the careful and meticulous pairing of each comparable unit of either set of chromosomes. Now there is a form of mutation which is sometimes observed wherein the actual number of chromosomes changes. Since different species have different numbers of chromosomes in their cells—and a plenitude of these incidentally seem to correspond in no way to height attained on the evolutionary ladder—it is reasonable to assume that such mutations have happened in the past. In other words the reason why two kinds of creature, perhaps externally very alike and perhaps until recently interbreeding, cannot produce offspring, may lie hidden in the nuclei of their cells which in their chromosome content have become incompatible. Then the married sperm and ovum will no more produce life than would the spare parts of a tractor's and a motor-cycle's gearbox mix to form anything workable, or—to seek to avoid that pitfall of ever mechanical similes—would Red Indians and Louis XVI aristocrats combine in a really successful minuet.

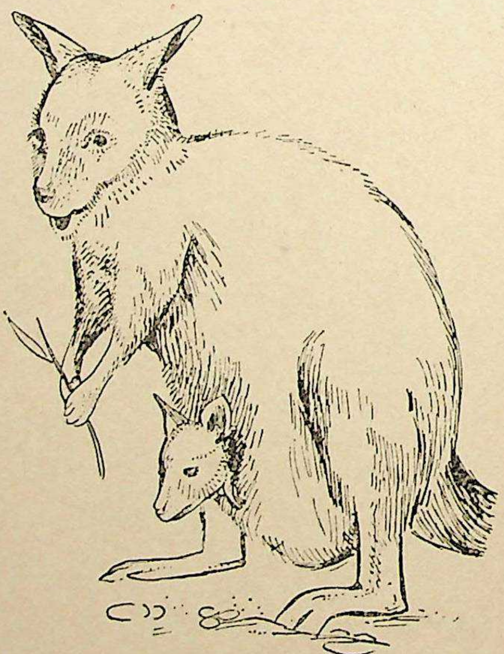

FIG. 64. Does baby-in-a-bag make jumping more possible?

The answer then to the question, how can Natural Selection cause new species to be formed is: physical separation and the ensuing adaptations to different environments continuing on their separate and divergent paths until interbreeding becomes an impossibility. One can add that if something of the sort did not happen it would be a poor lookout for Evolution, since otherwise any particular nice adjustments to environment would be nullified whenever separated animals re-met and re-fused their characteristics: you would tend to get not bright variety but dull uniformity, just as to mix the glowing colours of a child's paint-box is to produce a muddy brown.

Now we come to a question much more difficult to answer satisfactorily in Darwinian terms.

It is this: how can Natural Selection, working on chance variations, evolve such complicated and delicately co-ordinated organs as an eye or a wing? On the Darwinian theory, the questioner may point out, any variation has to be of *immediate* value to its possessor if it is going to give him a better chance of survival than his fellows. Of what 'survival value' is the first dim beginnings of an eye, or forelimbs starting to flap about feebly and nakedly in anticipation of a wing?

The example of the eye is that taken by the philosopher Bergson who insists that there is a driving force behind Evolution, the *Elan Vital*, and that without it nothing so marvellous as the eye could have been formed. One way to combat this is to say that nature does in fact show an evolution of the eye from the dimmest of red spots sensitive to light of such a creature as Volvox, and that even the dimmest would have survival value as would equally the slightest improvement. Another way is to tackle more boldly, as J. B. S. Haldane has done. There are only four ways of creating an eye, he says: as an insect does; on the basis of a pin-hole camera; on the basis of a camera with a lens and diaphragm; or on the basis of a telescope with a reflector. Vertebrate and mollusc (cephalopod) have evolved the third type, which is efficient, but no animal has evolved the fourth type, and it is just that kind which would be the most difficult. It is all in fact what one would expect; and this or any other example of 'parallel evolution' where totally different kinds of animal produce quite independently the same kind of organ or limb or other adaptation to their environment, is not an argument, as some would hold it, for design or purpose behind evolution but merely a matter of evolution taking the line of least resistance, the best or the only possible course. Mutations can produce advantages to their possessors so subtle and minute that the human investigator will be unable to detect them ; but they will be acted upon nevertheless. It is rather as if an unknown hand were to sprinkle a piece of paper with, shall we say, pepper but were to substitute in a devious course some less unpleasant powder of identical appearance, some ambrosial substitute. Place a voracious worm down on the paper, and his opportunism will undoubtedly route out for him that devious course—whereat the spectator will wonder and begin to propound ingenious and unnecessary theories.

The *wing* criticism is, it seems to me, more difficult to answer. We come back to our friend the 'ancient wingéd one', *archaeopteryx*. How *did* he change his scales to feathers and his front legs into wings ? How tempting to say that it was because he was wanting and trying to, or at least that each successive generation, flapping away, produced by use and desire better adapted muscles, better *knack*, such knack and muscle being inherited ! But apparently we must not do that : inheritance is something particular and inviolate within the nucleus of the cell, and no Lamarckian acrobatics on the part of the mother are likely to alter her chromosomes.

What we must do, rather, is to talk in terms of *mutations*. And there is a horrible danger there too.

It is true that the discovery of mutations in the make-up of the chromosomes does alter the whole Darwinian outlook. They are so obviously something more than mere 'variations', the playing on the same old theme of what characteristics the parents have to give their offspring. It is what the parents have to give that changes, suddenly and permanently. Linnaeus said 'Natura non fecit saltum' ; but now we say that this on the other hand is just what does happen, Nature does go in jumps.

The question is, how big jumps ? And that is the horrible danger : the temptation to jump oneself to the easy explanation that jumps can be tremendous. In plain fact most mutations, or rather, to speak more accurately, the observed results of those mutations, are small. Nevertheless, the possibility of big jumps cannot be absolutely denied.

Are we left then with archaeopteryx suddenly appearing as a freak of nature, horrifying its parents, and then proceeding to fly ? It looks as if we are, though naturally in a somewhat less exaggerated and ludicrous form. It is the same with the fish who first walked on

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his fins. The vertebrates' forelimbs have certainly a lot to answer for. So have the strict Darwinians. There is not in fact a wholly satisfactory answer.

We can now turn to a question where modern orthodoxy gives a much better answer. 'Does not then,' the man with a lingering regard for Lamarckianism may ask sadly, 'does not Use and Disuse have any influence in producing new characteristics?' He might add persuasively: 'Take disuse in particular. What about the mole or the cave fish that have nearly or wholly lost the use of their eyes, or the snake, that you say was once a lizard and has only vestigial legs?'

The answer is that disuse only *seems* to have an effect, an hereditable effect that is to say. For Natural Selection, it must be remembered, works both ways and bad mutations are occurring all the time just as are good ones. In other words, every time a mutation for poorer sight occurs in normal fishes in the light, it will gradually be bred out of the species by reason of the fact that those inheriting it finally die out. *Not so* however the fishes in the dark cave, where bad sight is no hindrance to them and where such a mutation will remain unchecked and will not be bred out but bred in. The same with the mole; the same with the snake. It is believed incidentally that the snake in its evolution went through a period of burrowing and underground life where legs would have been not only useless but a definite hindrance.

Where the orthodox will be on less firm ground will be if they add: 'And of course *use* is merely the opposite of disuse.' For it is a disturbing fact that, in the laboratory at least, harmful mutations are far and away more frequent than those that could possibly be seized on as beneficial. Indeed there are those who say that Natural Selection, being in essence a matter of killing off, is no more than a negative force and so cannot possibly be either the prime or only begetter of Evolution. Again not entirely satisfactory.

Here is another question that the critic may ask, but where he will get an answer that does not so much refute him as take the wind out of his sails.

'How,' he may demand, 'do you interpret in terms of that favourite expression of yours, "survival value", such things as the tail of a peacock or, equally gorgeous but equally unuseful, the fan of an argus pheasant? I should have thought,' he might add rather sententiously, 'it was purely a matter of God's creativeness of Beauty!'

To which the Neo-Darwinist might well reply: 'As to beauty I agree with you, though I think it rather confuses the issue; as to survival value I agree with you also! You have not yet properly realized how Natural Selection works.'

Charles Darwin wrote a great deal about birds' plumage and display and generally about what he called Sexual Selection, which he regarded as a particular aspect of Natural Selection. To some extent he was obviously right in this. Rivalry between males is, one might say, nature using the passion of love very neatly for her own business of weeding out the less fit—in the fight to the death nature has the whole thing worked out to perfection. But Darwin is one man and modern bird watchers and evolutionists are legion, and most people would say nowadays that Darwin over-simplied matters a good deal.

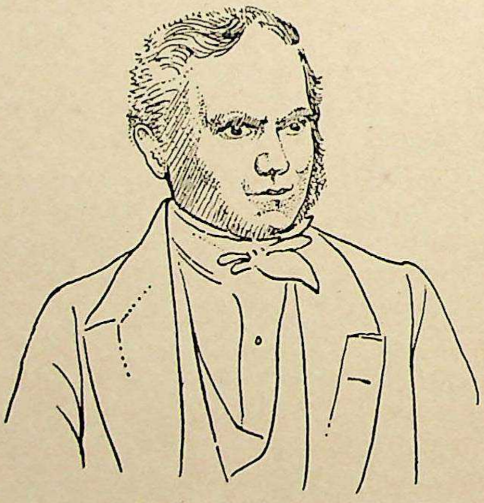

FIG. 65. Charles Darwin
(from an early portrait)

For one thing, very few creatures, birds included, really do fight to the death. Secondly, birds are, as we know, most curious creatures in their behaviour and to try to interpret this in terms of a sort of romantic medieval chivalry is to misinterpret it entirely. The reeve, by all accounts, does not choose the most resplendently collared

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ruff. What exactly governs her choice nobody knows; it may be a male fascination or dominance we are unable to perceive, or on the other hand it may be that the general strutting excitement has released the trigger of her desires at the precise moment when A, B or C happens to be showing off to her.

That the most attractive plumage is being worn by the healthiest or the most forceful and 'fittest' bird is possible and even probable. But to say that the gorgeous plumage of a species is of survival value to that species is a very different thing and in fact is just not true. In plain words there are two kinds of competition, between different species or inter-specific, and between the members of one species or intra-specific. And though the latter will usually help a species to keep up to the mark it may very well, and often does, run away with itself and become so exaggerated as to be a serious liability instead of an asset to the species as a whole. Conspicuous plumage is not in the least a help to a bird to keep away from its enemies. A deer's antlers may be spectacular weapons with which to win and keep a harem but are about as much use in life, one would imagine, as going about with a hatstand on one's head, and a hatstand incidentally which one has had to make out of one's own bone and blood. A suggested cause for the extinction of the showier and hornier reptiles is that they had gone sexually and intra-competitively mad. The stegasaurus with a row of giant tiles along his back and down his tail a little bigger and tougher and spikier than his sexual rival may have survived over that rival to perpetuate the species. But half his life force had gone into the creation of those spikes, and the other half was not enough to save the species when the crisis, whatever it was, came along. The same sort of reasoning can be legitimately applied to the showiness of butterflies or the meticulous mimicry of insects: the creature could get along without it, but it is not impossible to suppose that competition, either intra-specific or between like species, *could* produce these gorgeous or fantastic exaggerations. Natural Selection in fact—and it will be remembered that we have had to say this about so much of nature—is hit-or-miss, casually even flamboyantly hit-or-miss. But—so say the modern orthodox Darwinists—*it gets there just the same.*

And that introduces the last and the largest and widest and deepest objection to Natural Selection as the true and only tool of Evolution. It is both more and less than a criticism; it is often a violent and instinctive shying away in disgust. Natural Selection is so *mindless*. It is so purposeless. It is the apotheosis of Blind Chance.

People's reactions here are largely governed by their character and their upbringing and perhaps for that reason are usually violent. They goaded George Bernard Shaw to write a brilliant polemic, in the shape of the Introduction to *Back to Methuselah*, advocating a sort of revolution in faith based on Bergson and Lamarck. The irritated reaction of the scientist to this is typified by Julian Huxley who dismisses Shaw's effort in one sentence by dubbing it wishful thinking and scathingly remarking that to say a thing *ought* not to be so does not *make* it not so. That, as a generalization on this subject, is a useful remark to make: it is of no use to dismiss Natural Selection just because we cannot bear the thought of it. But so facilely to dismiss a rival theory conceived by a brain which is outstanding if it is not strictly scientific surely shows an emotional reaction rather than a rational one. Shaw in rich and pungent language showed up the great geneticist Weismann for the fool he could be on occasion. Weismann, in order to prove that characteristics acquired during a lifetime could not be inherited, took—a sort of professional Farmer's Wife, B.Sc.—some mice and cut off their tails. He took their children and cut off their tails, and their children's children and their children's children's children. Finally, when he was tired, or impatient, he produced the most recent generation and pointed out in triumph that they still had tails. To assume that habits and characteristics acquired in nature and through a lifetime should have any similarity with this purely arbitrary and extraneous act of Professor Weismann's knife was surely one of the silliest things a man of intelligence ever did; and it would have redounded very much more to the credit of scientists as a whole if they had not left it to one entirely outside their fraternity to make a fuss about it.

But let us leave this, lest we also become too heated. Shaw's *Back to Methuselah* is important because it does put so forcibly this reaction against the Darwinian theory of Evolution on the ground that it appears so mindless and purposeless.

Is Natural Selection mindless and purposeless? I think that we have to admit that, so far as our present knowledge goes, it is. The discovery of mutations does seem to put some sense and order into things—Darwin's 'random variations' do not sound quite so random when you explain that they are caused by a definite and apparently permanent change within the cell. But no one knows why mutations

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occur and until we do we cannot legitimately impute anything more than pure accident to their sudden arrivals.

What then, this being so, are we going to make of this mindlessness and purposelessness? What have other people made of it?

There are various reactions. The first is the reaction of what we may legitimately call, I think, the hard-boiled and insensitive kind of scientist. His reaction is almost a crow. 'What else did you expect? Why should it not be? And if it is, it is! You can still invent your Gods and Divine Purposes if you like, you can still put them on top of the whole edifice. But don't mix them up with scientific facts and don't ask me to believe in them!' Such a crude and unhelpful reaction is, I think, fortunately rare.

The still strict but more sensitive scientist acts differently. He seems perversely to be able to take hope from the very gloominess of the picture. 'Granted it is all purposeless,' he says, 'but see how there is the appearance of purpose!' 'Behold this little thing,' they say, 'this rather nasty thing, this lethal thing, Natural Selection. And what finally comes out of it? Man!' All's well that ends well.

This is not to say that there still exists the crude toughness plus complacency of the nineteenth century: emulate Nature Red in Tooth and Claw and we shall reach a millennium! Julian Huxley, who I think can be taken to represent the strict but sensitive kind of scientist, sets out an idea something like the above. Natural Selection, he says (in *Evolution in Action*), 'converts randomness into direction, and blind chance into apparent purpose'. With time to help it, 'it generates results of a more than astronomical improbability, which could not have been achieved in any other way.' But it can only work for *immediate* biological advantage, and it can thus result in blind alleys from which there is no evolutionary escape and which often end in degeneration or even extinction. That however is not all. Natural Selection produces 'biological improvement' and this not only in the narrow sense of more and more specialized adaptation to environment. There is improvement in the general mechanism of living, as a steam engine or any other of man's inventions is gradually improved; there is finally 'improvement which permits, or facilitates further improvement' and that merits the name of 'advance'.

J. B. S. Haldane has something of the same approach. In *The Causes of Evolution*—the book in which he discusses the ways of creating an eye—he too admits that Natural Selection is mindless.

But what else, he asks, would you expect? He then points to something of what I have tried to cover in the chapters on the evolution of behaviour, the increase in sensitivity and intelligence, and says virtually: now *mind* has arrived; now indeed and for the first time mind can direct Evolution, and it is up to the possessor of that mind to see that the results are good.

So in fact—though of course with much variation—say the orthodox modern biologists. Nevertheless, many laymen—so I should guess—and some of the biologists, are not satisfied.

'Granted,' they say (so we can imagine), 'all the time in the world, all the luck in the world, all the anything you like in the world within your philosophy! But we do not see, we *cannot* see, that Natural Selection working on chance mutations can have produced this modern world, with all its living variety, its miracles of efficiency, ingenuity and elaborate beauty, and above all with the intelligence of man. There must be something else. There must be something which you have not even begun to see because you are not trying to see it, because you are not thinking in the right way to see it.'

The views of these unorthodox scientists we will discuss in the next chapter.

CHAPTER XXIV

The Unorthodox

THE viewpoint and theories here expressed are those of an anatomist, Professor F. Wood Jones, a biologist, Dr. E. S. Russell, and a Doctor of Medicine, Sir Walter Brain. There are no doubt others of the same way of thinking, whose books I have not read. All three of them, being scientists of high repute and realizing their own unorthodoxy, have put forward their views with some tentativeness, though that has not prevented them from being pungent and forceful when they felt that occasion demanded it. We could call them Vitalists, or New or Neo-Lamarckians ; but it would be better if as far as possible we avoided giving them a label but listened without prejudice to what they had to say.*

The argument begins, I think, with something very like the quotation from J. H. Fabre in the first chapter of this book, wherein he challenges a hypothetical scientist who had made synthetic protoplasm to do anything with it before it went bad on him. The argument really now starts farther back, for even protoplasm has a stirring restlessness. Life, it is asserted, is something on its own, an entity *sui generis.* Its manifestations may be described chemically and physically, *but that explanation will never be the whole explanation.*

It is what living things do that matters, not what they are.

It is function that matters, not form.

Here should follow a historical survey, to make it clear how the old non-vitalist outlook has arrived, why it is so inadequate and how extremely difficult it is to acquire the new outlook. We must take much of this as read. The point, which I think nobody would dispute, is that the nineteenth century was particularly successful in the mechanical and chemical branches of scientific knowledge and as a result developed a particularly mechanistic and materialistic outlook. Darwin's theory fitted so well into this mechanist philosophy that his contemporaries thought that way, one might say, without even realizing that there was any other way in which to think. They studied, with terrific application and great success, animal form, but not animal function. They sought always to explain what they discovered about life in mechanistic simile.

---

* The notorious Lysenko is not in this category at all. He made fantastic claims for the powers of clever husbandry to change heredity. But apparently he is now discredited even in his native Russia—as a biologist, that is to say, though not necessarily as an agricultural administrator.

That is a pitfall that we in this book have noticed more than once already though not always avoided. In this age one seems to gravitate almost inevitably towards a mechanical simile in explaining things—and then to take the explanation not as a parallel but as a fact.

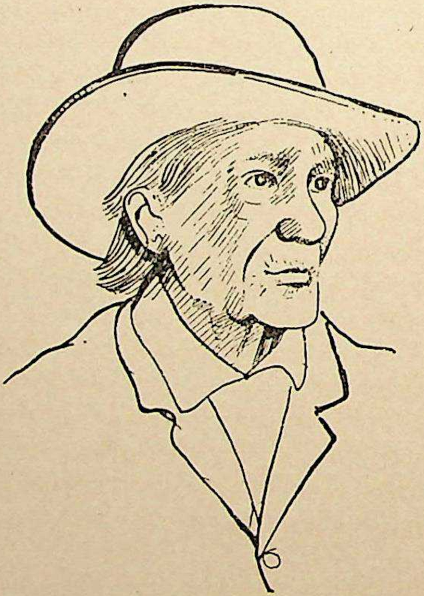

FIG. 66. J. H. Fabre

That is just what we must not do where life is concerned. A little thought will convince us of that. Recall for the last time that protoplasm of Fabre's and its ability to spread itself out into the intricate veined beauty, and efficiency, of a cicada's wing—to fill a mould, but where no physical mould exists. Think of the beginning of any life, of any seed, vegetable or animal—zygote is the correct term, but a seed is also a zygote and seed is the word with greater meaning and implication for us. Take a seed, any seed. How does it *know*, infallibly, how to become a poppy or a foxglove or a sycamore tree—how does it know how to become a sycamore tree or a tadpole or a

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monkey or a man? What guides it? What is there, *within it*, that guides it? We know, the embryologists know, a great deal of what happens, of the stages, each one depending on the one before, even of the chemical processes and what transpires if you interfere with the processes this way and that way. But we cannot begin to explain why it happens and what really makes it happen. Nor can we begin to pretend to ourselves that all that is necessary is within that seed, *physically*, from the start.

It is not a matter of space, it is a matter of time. It is a matter, presumably, of influences, directives, of pre-ordained patterns in time that must fulfil themselves. And the thing to appreciate about all this is firstly how difficult it is to describe in words, how difficult it is to visualize—and above all how wrong it is to react impatiently to these difficulties by calling all explanations that do not use the terms of chemistry and mechanics and physics unscientific and mystical. They are nothing of the sort. It is in fact often more important to consider what science does not know or cannot adequately explain than what it can be legitimately glib about—and science has often sinned in not drawing attention to its ignorances or even of being glib when it has no right to be glib.

The new idea, then, is not mystical but merely more difficult to envisage or explain. Now we can try to see whither it leads us. Consider any form of life, simple or elaborate: what is it trying to do? It is trying surely to maintain itself and its species. It is struggling with its environment, to master its environment, to eke out a living from its environment. It has its needs and it tries to meet them.

It is not, this creature whatever it may be, something entirely passive, merely moulded by its environment. It has its own initiative. It struggles and contends—we can be at one with Darwin in the word 'struggle'—and it wins or loses. Life, say these new unorthodox scientists, is *directive*. In one single sentence, paraphrased only slightly from Professor Wood Jones: the developments of the living organism are directed towards the ends that those developments will serve. No theory that cannot be aligned with that concise definition should be entertained, however satisfactory it may otherwise seem; no theory that entertains it should be discarded merely on mechanistic or anti-teleological arguments.

Now we come back to Lamarck, or rather, as these scientists would say, to ideas that seemed common sense to most naturalists until Darwin half refuted and the Neo-Darwinists wholly refuted them.

Creatures, in their achievement of a more successful life within their environment do three things:

change and develop their habits;
change and develop the use of their organs;
change and develop their forms.

That so far is irreproachable.

Now take as example a series of creatures meeting the particular need of protection, either against enemies or climate.

First, some of the lowly molluscs. They already have a shell; but they may need to close that shell. The common English garden snail when—or perhaps rather if—the hot dry weather comes, finds a flat stone and fastens himself on to it. The same snail in Australia, needing something more efficient, or lacking stones, finds the solution, both metaphorically and literally, within himself, and closes the opening with his own secretion. The winkle, too, follows this second method of forming a secretion. But some tropical shell-fish actually *grow* a front door on to the end of themselves, which fits perfectly. Similarly some spiders *make* a trap-door to their underground home, some *grow* it. And then marine worms will either burrow for protection (habit) or make a tube from their own secretion (use of organs), or develop a hard resistant cuticle (change of form).

Now all those are examples of life effecting developments 'directed towards the end that they will serve'. *Why*, runs the new argument, should the first two be allowable as perfectly normal happenings needing no special explanation, while the third, the changing of the form of the body, has to have foisted on to it the difficult and cumbersome explanation that it could not have happened except by a long series of chance mutations seized upon by Natural Selection?

The Darwinian answer to this is to seek refuge in the lack of any proof of the inheritance of acquired characteristics, and to point out that if succeeding generations are to grow the new bodily form that has been produced to meet a specific end, protective trap-door or whatever it may be, then there simply must be this kind of inheritance —which just does not exist.

Here is a genuine difficulty. The counterblast of the unorthodox

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is, as I see it, a double one, comprising first a bold and direct attack and secondly a more subtle insinuation which may in fact seem less satisfactory but is nevertheless the more important criticism of the two.

The first is to declare roundly that no one has really disproved that in Nature acquired characteristics are not inheritable. The experiments in the laboratory are not so demonstrably silly as Weismann's with his carving-knife but they are of the same order. In Nature life is striving of its own initiative to serve its own ends, not suffering man-made disabilities. Further than that, *time* comes very much into the picture; and for once, because he wants to, the Darwinian is discounting the importance of time. Can Man live a million years to observe results, can he even live a thousand? 'You have had a hundred or so generations of fruitfly and observed no change! So what? For that matter and for all you know, evolutionary change may go not by length of individual generation but by absolute time: drosophila may change no more rapidly than Homo Sapiens—perhaps even more slowly since there were fruitflies in the world undoubtedly before there were men!'

Again, however, the argument is negative. There are to refute it those chromosomes, inviolate and uninfluenceable within the nucleus of zygote cell.

But *not* the genes. The genes are only assumed.

Here comes the second argument. It is not going to try to discountenance the existence of the genes. It is simply going to stress the fact that the gene is a directive; an influence; a function; something the importance of which is not what it is but what it does. All scientists of course recognize this; but the Neo-Darwinists —so this present argument goes—pay little more than lip service to it.

The reader will remember the list, at the end of the chapter on genetics, of the believed effects of various genes. That was admittedly compiled for a set purpose, to show that there was obviously a great deal that we did not yet know. But we can infer something more. It is that the gene is the very reverse of a packet of lifeless chemicals producing results as predictable as that you can get copper sulphate by heating copper and sulphuric acid together or that one part of oxygen and two of hydrogen will produce water. The gene has been called by one of our three authors, Sir Walter Brain, as perhaps no more than 'the number on the bus'—a directive. And its physical

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constitution might be almost as lacking in significance as is the paper and printer's ink that constitute that bus notice.

So, in fact, we do not know enough about the functioning of the gene and of heredity—the functioning, not the mechanism—to lay down the law about them and in particular to deny that acquired characteristics can ever be inherited. Because there seems no possibility of the chromosomes of a zygote being *physically* influenced by the mother's body in which it is developing, are we to deny any influence? If we cannot see a gene, have we the right to deny hereditary influences upon it that in the nature of things would themselves be invisible? Or for that matter, can we not plead what the Darwinists have pleaded so often when they have suffered from missing links in the fossil record, and assert that lack so far of a positive proof of the inheritance of acquired characteristics does not disprove what so much else seems to show as the only reasonable solution?

Alternatively, if we must accede the inviolability of the genes in the chromosome, why should we not go a little farther back in the reproductive process, take mutations, remind ourselves that no one knows what makes them happen in Nature, and suggest that the directiveness of life, reflected in a newly acquired habit, skill or characteristic in the parent, should be the very cause of a mutation? And as for that mutation, may not an environment do more than merely favour it, may it not *stabilize* it within a few generations, by as it were encouraging the genes to steer the development of the embryos in a new way?

All that is not very easy, or perhaps very satisfactory. But that is to be expected. For this is essentially a different way of looking at things, with the stress always on function and not on form. Perhaps what we have really to try to understand is pure function without form. At least it seems certain that the seed that grows, the protoplasm that flows into the forming insect's wing, the gene that governs the embryo's growth, all work in a way that becomes not the more but the less intelligible if we seek to explain it in terms of chemistry or physics or spatial measurement.

And that is about as far as we can take the argument based on the books of these three unorthodox scientists. It is a matter essentially of a new outlook—if, says Sir Walter Brain, Darwin was the Newton of biology, what is now awaited is its Einstein.

Without pretending to this eminence we can at least appreciate that this outlook—the idea that we should always try to think in terms of function not form, the idea that life is something both

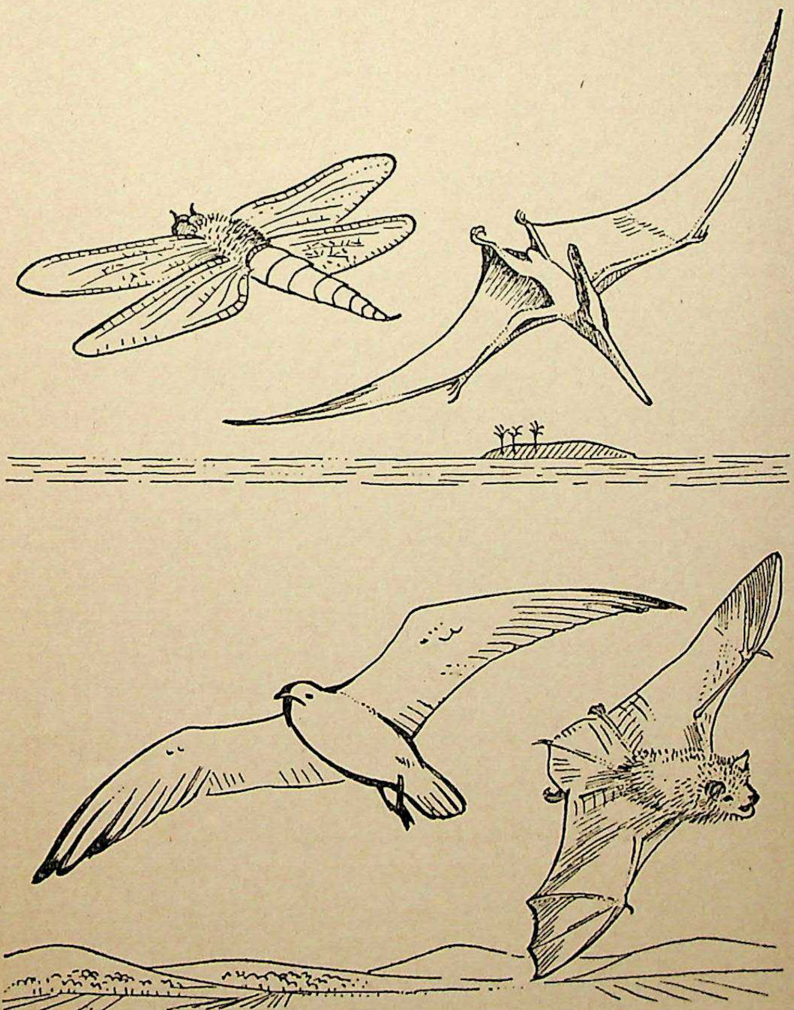

FIG. 67. **Function and form: the four conquests of the air**

unique and with a power of initiative and directiveness—is one to be taken seriously. 'At the risk of being labelled a teleologist,' says E. S. Russell, 'I maintain that biology must recognize and accept directive activity as an "irreducible charasteric" of life, and make a steady effort to establish the laws of this mode of activity.' It is a way of looking at things that might help us to understand a whole series of problems that certainly do not seem to be responding to mechanistic treatment. Here for instance are a few miscellaneous and disconnected items: why is a gene so like a virus and in what way is a virus (or a gene) alive; how do social insects communicate with and influence each other; how and why do insects and plants mimic their near neighbours; how do birds receive their indelible imprints of behaviour pattern; and, once more and most basic of all, how does the developing seed, animal or vegetable, *know* how to develop? Perhaps the new method will help—if we can only master it. It needs clear thought and a stern discipline: not to wander off into wooliness, wild bouts of intuition, or mysticism.

Finally two tail-pieces to this chapter.

One is that few people would deny all power whatsoever to Natural Selection. At the least it would be allowed to have produced, to quote one of these three authors, 'the bizarre and the beautiful'—the fan-tail of the male argus pheasant for instance that seems to cause so much controversy.

Secondly here is that promised last word about the evolution of the long-necked giraffe. The female of the species, it is said, grows about two foot shorter than the male. In which case one wonders how any mother-to-be was ever 'fit' enough to survive. The whole argument is artificial and over-simplified.

NOTE.—The books that have given rise to this chapter are:

Trends of Life. By F. Wood Jones, F.R.S. (Arnold, 1953.)
The Directiveness of Organic Activities. By E. S. Russell. (Cambridge, 1946.)
Galatea or The Future of Darwinism. By W. Russell Brain. (Kegan Paul, in the To-day and To-morrow Series.)

CHAPTER XXV

Conclusions

THE story has been told and the theories reviewed. I hope it will be agreed that two things stand out: the story is well documented and makes sense; the theories are somewhat in a state of flux.

It should be possible to state the irreducible minimum of what is established. I suggest it is this:

> Life has developed from the simplest beginnings to a tremendous variety.
>
> There appears a great driving force behind life which urges it to take advantage of its opportunities and to adapt itself successfully to its environment—and with something to spare in the shape of exuberance.
>
> It can do this by means of an increasing specialization which leads to some kind of dead end.
>
> Or it can do it by an increasing sensitivity and an avoidance of specialization, which has led to mind and consciousness and man.
>
> The means to these ends have been either the blind force of Natural Selection or an innate property of life to maintain itself and develop means with which to serve towards that end: the matter is in dispute.

But again, appreciate two things. First: whatever may have caused evolution, man has in fact arrived; and whatever bitter or cynical view one may feel inclined to take about man at the present one must admit at least that his potentialities are enormous and that Hamlet's eulogy, already quoted—though spoken indeed in a bitter mood—is not wholly unwarranted. That makes the story of evolution, I feel, a cheerful and inspiring, not a pagan or pessimistic, one: Nature, as Sir Charles Sherrington says, may be non-moral but it has at least produced moral and altruistic Man.

Secondly, note that no one—at least no one of importance so far as I am aware—has denied that there may be a purpose behind

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it all. The Neo-Lamarckians, if I may give them that name, are careful, in propounding a directiveness in life, not to impute a conscious directiveness in any individual emanation of that life; the Neo-Darwinians conversely are careful to suggest that the blindness of natural selection may only be an apparent blindness and that a higher guidance in no way need be denied. 'God,' we often quote approvingly, 'works in mysterious ways his wonders to perform'; and we should not be too put out if he chooses natural selection or mutations as his tool rather than something noble-sounding like the Life Force.

This may sound a trifle flippant. But that is really the most serious purpose behind this book: a hope that it may help to heal the breach between the scientist and the theologian, or, to put it a little lower, that it may help to persuade the orthodox Christian—or even the Laodicean but professed Christian—that evolution is not something taboo.

For the best part of a hundred years people have been saying cosily that there is really nothing to quarrel about, but for the best part of a hundred years the quarrel has continued: it is surely time that the rumpus that *The Origin of Species* caused should cease, even in its echoes, to make incredible the still small voice of reason. Evolution is not worthy of taboo, it is important and it is interesting; and perhaps one day soon parents and guardians and other responsible people will not only find this out for themselves but insist that school teachers should have a little more courage and see that evolution is brought into the study of biology in schools from which as far as I can discover it is at present very largely excluded.

I am not thinking of the Fundamentalist. The Bible has some lovely and wise things to say about life and the beginnings of life; but if the reader insists upon a literal meaning, or rather his own idea of the literal, then there is not very much that can be done about it. But to the more reasonable Christian there are admittedly two great difficulties. One is the brutal blindness of Natural Selection as the Great Cause—though curiously that does not always seem to have worried the orthodox as much as such highly unorthodox individuals as George Bernard Shaw. The way to deal with that difficulty is I feel not to set up against the literalness of the scientist the intuition and superior insight of the artist, as for instance Jacquetta Hawkes does in her book *Man on Earth*, in which she confesses her final disbelief in Darwinism to have been caused by a moment of insight on viewing the 'fine and energetic baroque' of the displaying argus pheasant: that merely annoys the scientist without convincing the religious. The way is to set careful observation and close theory against careful observation and close theory, as I believe do the three authors whose work I tried to summarize in the preceding chapter.

The greatest difficulty for the Christian is the soul of man. 'He who believes,' said Darwin, not unnaturally aware of this difficulty, 'in the advancement of man from some low organized form, will naturally ask how does this bear on the belief in the immortality of the soul.' He adds:

> Few persons feel any anxiety from the impossibility of determining at what precise period in the development of the individual, from the first trace of a minute germinal vesicle, man becomes an immortal being; and there is no greater cause for anxiety because the period cannot possibly be determined in the gradually organic scale.

How helpful most people will find that I am not sure. I see no chance however of being able to stick with any show of reason to the belief that man is physically a separate creation. Perhaps it is helpful to regard soul as an emanation of mind and then to be quite clear that mind though an emanation of brain is something quite

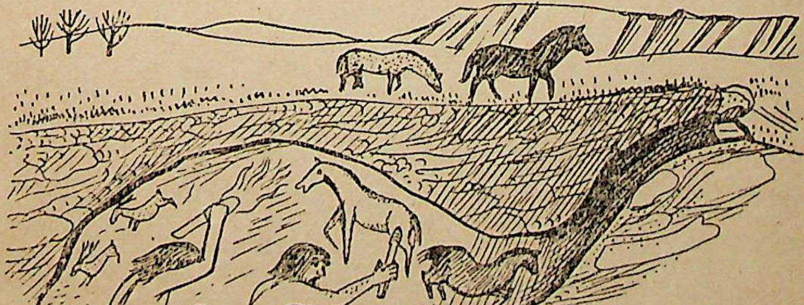

FIG. 68 The birth of understanding

different and on a separate plane. One can indeed go further and say that all evolution is epitomized in the slow development of mind, even that that essential *difference* of the living from the non-living, that unique quality of life, is the embryo of mind—that the whole purpose of Evolution, 'a purpose not yet fulfilled', is the growth of mind and consciousness, which is soul.

But I am not equipped to philosophize and this book will not attempt it.

This only will it assert: a man's philosophy is likely to be truer and deeper if he has a knowledge of biology and organic evolution. Heaven knows we are artificial enough these days in our town-bred existence. A little feeling of oneness with the rest of life may even make us as intelligent and as sensitive as the men who, thrilled and awed and elevated at touching the skirts of creative understanding, painted the cave walls of Lascaux and Altamira two hundred long centuries ago.

Index

Acorn worm, 59
Acquired characteristics, 230, 248
Africa, 159–62, 171
Air bladder, 62
Alice, 96
Alligator, 79
Altruism, 115, 204, 253
Amblypod, 86
Ammophilia, 110
Amoeba, 23, 27, 32
Amphibian, 69–71, 190, 196–8
Amphioxus, 58
Animal Courtship, 179
Annelid worm, 44
Ant, 112 *et seq.*
Anthropoidea, 150
Ape, anthropoid, 98, 148, 156, 162, 195
Ape, ground, 150, 203
Aphides, 102, 174
Aphrodite, 200, 224
Arachnid, 178
Arambourg, Prof. C., 172
Archaeopteryx, 124, 238
Archaeornis, 124
Archaeozoic, 42
Argus pheasant, 239, 252, 255
Aristotle, 226
Armstrong, E. A., 139, 143
Arthropod, 46, 47, 51, 67, 100, 178
Atlanthropus, 172
Atoms, 20, 22
Australia, 89, 234
Australopithecus, 158, 161, 167
Azoic, 42

Baboon, 84, 107, 150, 152, 203, 204
Back to Methuselah, 242
Bacteria, 19, 25, 207
Baluchithere, 86
Barnacle, 209
Bat, 94, 95
Beagle, H.M.S., 231
Bees, 111 *et seq.*
Beetle, 108, 179
Behaviour, 106, 128, 143, 172, 177, Ch. xix, 235
Bennett, Arnold, 91
Bergson, Prof. H., 237
Bible, *The*, 21, 44, 113, 117, 184, 195 225, 227, 254
Bilateral symmetry, 37, 58
Bird Display and Behaviour, 143
Birds, Chs. xi to xiii
—— and ceremony, 140
—— and emotion, 128, 142
—— and learning, 192
—— and nesting, 140
—— and sex, 131, 143
—— and song, 131–3
—— and territory, 131, 137
Birds' brain, 145, 188
Black, Dr. D., 164
Bletsworthy, *Mr.*, 211
Blood, 32, 44, 81, 99, 126, 216
Bolas, the, 171
Brachiation, 154
Brachiopod, 55
Brain, 36, 61, 75, 79, 89, 97, 122, 128, 145, 164, 180, Ch. xviii, 255
Brain, Sir Walter, 245 *et seq.*
Bristle-tail, 68
Broken Hill, 168
Broom, Dr. R., 160–2
Browne, Sir Thomas, 227
Brünn, 214
Bryozoa, 54
Buffon, Comte de, 228
Burton, Dr. Maurice, 179
Bush baby, 96
Butterfly, 103, 111, 241

Cainozoic, 42, 77, 87, 89, 93, 145
Cambrian, 42, 43, 47
Carbon, 21
Carboniferous, 42, 43, 68, 69, 100
Carmel, Mt., 168
Carnivore, 92
Cat, 92, 192
Caterpillar, 103
Cave painting, 166, 170, 256
Cell, the, 23, 28, 147, 173, 185
Centipede, 68
Cephalopod, 49, 177
Cerebellum, 187

Cerebral cortex, 187
Cheetah, 92
Chesterton, G. K., 90
Chimpanzee, 154, 195
China, 162–6, 212
Chlorophyll, 27, 65
Chordate, 58, 59
Christians, 118, 254
Chromosomes, 24, 216–18, 221, 236, 238, 249
Chrysalis, 103
Ciclid, 181
Cilia, 28
Clam, 55
Clark, Sir Wilfred Le Gros, 159
Class, 27, 85
Climate, 39
Coal Ages (*see* Carboniferous)
Cockroach, 102
Cocoon, 103
Coelenterate, 33–5
Cole, Sonia, 160
Colour, 54, 89
Coral, 54
Corpus striatum, 188
Courtship, 138, 175 *et seq*., 201
Crab, 47, 177
Cretaceous, 42, 43
Crinoid, 55, 57, 72
Crocodile, 79
Cro-Magnon, 166, 170
Cuckoo, 123, 135, 136
Cud, 91
Cuttlefish, 49

Daedalus, 53, 126
Dart, Dr. R. A., 160, 161
Darwin, Charles, 15, 139, 146, 214, 219, 228 *et seq*., 255
Darwin, Erasmus, 228
Deer, 87, 200
Deslys, Gaby, 139
Devonian, 42, 43, 65, 69, 70
Diatom, 28, 65
Dimetradon, 74
Dinichthys, 60
Dinohyus, 87
Dinosaurs, 70–80, 191, 212
Dinotheria, 85–8, 191
Directiveness of life, 247–52
Directiveness of Organic Activities, 252
Disney, Walt, 55, 201
Displaced emotions, 142
Display, 143
Dog, 190, 193
Dragon-bone Hill, 164, 165, 172
Dragonfly, 66, 103
Drosophila, 218, 222, 249
Dubois, E., 162–4

Earwig, 102, 108
Echidna, 83
Echinoderm, 47, 55, 57, 185
Ectocrines, 176, 181
Eel, 181
Egg, 72, 81, 103, 115, 134 (*see also* Ovum)
Elan Vital, 237
Electronic brain, 187
Elephant, 93, 126, 227
Elliott Smith, Prof., 83
Embryology, 247
Emotion, 107, 128, 142, 145, 173
Empid fly, 180
Endocrines, 176, 181
Environment, 38, 84, 146, 223, 233
Enzymes, 31
Eoantrhopus, 157
Eo-basileus, 86
Eocene, 42, 43
Era, 42, 43
Esau, 187
Euglena, 37
Eurypterid, 52, 53, 55
Eusthenopteron, 70
Evolution and advance, 212
—— and extinction, 25
—— and heredity, 214
—— and hit-or-miss, 137
—— and purpose, 256
—— and retrogression, 206
—— and the apes, 155
—— at work, Ch. xx
—— in schools, 254
——, line of, 84
—— of sex, 173 *et seq*.
Evolution in Action, 20
Eye, the, 22, 50, 52, 96, 97, 193, 237

Fabre, J. H., 19, 22, 108, 110, 119–21, 179, 214, 245
Fall, the, 205

Family, 27
Fayum, 158
Feather star, 55
Feathers, 81, 124, 199
Feed-back, 186
Ferocity, 76, 92
Fertilization, 29, 72, 105
Fire, 98, 156, 165
Firebrat, 100
Fish, 57, 71, 75, 77, 112, 180–3, 187, 239
Fisher, Sir Ronald, 25
Flacourt, De, 151
Flagellates, 27, 65
Flea, 100
Flight, 79, 100, 111, 126, 130, 138
Flint tools, 168, 171
Flowers, 105, 106
Fluke, 206–8
Food, 26, 64, 111, 129
Fossils, 40, 59, 147
Four o'clock plant, 219
Frisch, Karl von, 111
Frog, 70, 197
Fruit fly, 218, 222, 249
Function, 245 *et seq.*
Fundamentalism, 15, 69, 254
Fur, 81, 199

GALAGO, 96
Galahad, 132
Galapagos Islands, 231
Galatea, 252
Galley Hill, 169
Gametes, 216, 217, 221
Gemmules, 214
Genes, 22–5, 218 *et seq.*, 249–52
Genetics, Ch. XXI, 235
Genetical Theory of Natural Selection, The, 25
Genus, 27
Gibbon, 154, 155
Gibraltar, 168
Gigantopithecus, 212
Gills, 50, 62, 68, 71
Giraffe, 229, 252
Gloag, John, 92
God, Man, and the Universe, 224
Golding, William, 169
Gonads, 131, 176
Gorilla, 154, 155
Gosse, Philip, 231
Graptolite, 55
Grass, 91
Grasshopper, 102
Grub, 103

HABIT, 229
Haldane, J. B. S., 237
Hamlet, 173, 206
Hand, the, 96, 97, 148, 149, 171, 193
Hand-axe, 170, 171
Hawkes, Jacquetta, 254
Heard, Gerald, 91
Heart, 48, 126
Heidelberg Man, 170
Hen, 192
Heredity, Ch. XXI
Hermaphrodite, 175, 176, 207
Heron, 141
Hesperornis, 124
Hibernation, 95, 101
Holocene, 42, 43, 149
Hominoidea, 150
Homo Faber, 156
Homo Sapiens, 156, 170, 195, 196, 249
Honeydew, 114
Hormones, 99, 131, 175
Horse, 69, 87, 91, 192
Howard, Miss Len, 123
Hudson, W. H., 123, 142
Huxley, Julian, 20, 22, 31, 128, 138, 148, 242, 243
Hydra, 34
Hymenoptera, 106

ICE AGES, 39, 88, 167
Imago, 102
Imprinting, 192, 252
Ingestion, 26, 31
Inheritors, The, 169
Insectivores, 94
Insect Natural History, 104
Insects, Chs. IX and X
—— and communication, 119
—— and co-operation, 115
—— and flowers, 105
—— and food, 110
—— and instinct, 106
—— and metamorphosis, 101, 102
—— and reproduction, 108
—— as social animals, 107 *et seq.*
—— behaviour, 178–80
—— learning, 191

Instinct, 106 *et seq.*, 145, 173
Intelligence, 145, 173 187
Irritability, 32, 184

JAVA, 162–6, 170
Jelly-fish, 33–6, 185
Jerboa, 152
Jones, Prof. F. Wood, 245 *et seq.*
Jurassic, 42, 43, 81, 124

KANGAROO, 83, 152
King Solomon's Ring, 192
Kinkajou, 96
Knack, 238
Koehler, W., 195
Koenigswald, von, 164

LACK, D., 139
Lamarck, Jean Baptiste, 16, 225, 228–30, 232, 238, 247
Lamp shell, 55, 72
Lancelet, 58
Larva, 103
Lateral line, 61, 197
Leakey, Dr. and Mrs. W. H., 159
Leks, 143
Lemaitre, Canon G., 17
Lemur, 97, 151
Libido, 144
Light, 21, 65
Linnaeus, 227, 238
Liver fluke, 206–8
Living Brain, The, 69, 185
Lizard, 79, 127, 198
Lobster, 46, 75
Lorenz, K., 139, 192
Love, 76, 97, 133, 139, Ch. XIX
Love-darts, 176
Lull, R. S., 157
Lung fish, 63
Lyell, Sir Charles, 230
Lysenko, 245

MADAGASCAR, 151
Maggot, 103
Malthus, Thomas, 230, 232
Mammae, 82
Mammal, 77 *et seq.*
—— and teachability, 192
Mammoth, 93
Man and the apes, 155
—— and chromosomes, 218
—— and genes, 223
—— and insects, 101, 102, 107
—— and other mammals, 146
—— and the Primates, Ch. XVI
—— as social animal, 107
Man on Earth, 254
Man on His Nature, 128
Mandril, 152
Mantis, 180
Marsupial, 83, 89, 234
Medusa, 34
Mendel, Abbé, 213–15, 219
Mermaid, 93
Mesozoic Era, 42, 73, 77–9, 101, 104, 149
Metabolism, 128
Microbe (*see* Bacteria)
Migration, 130
Miller, Hugh, 53
Millipede, 68
Mimicry, 241, 252
Mind, 172, 180, 190, 255
Miocene, 42, 43, 160
Missing Link, 147, 168
Mississippian, 42, 43
Mistinguette, 139
Mole, 96, 239
Molecules, 21, 22, 26
Mollusc, 47, 237
Monkey, 97, 98, 152, 193
Monotreme, 83
Morgan, T. H., 218
Moth, 103, 111, 119
Mother, 72, 97, 109, 199, 202
Moulds, 25
Mousterian, 168
Mustard gas, 222
Mutations, 221 *et seq.*, 236, 238, 242, 252

NATURAL HISTORY MUSEUM, 92
Natural Selection, 232, 237, 239, 242, 252, 254
Nautiloid, 49, 55
Nautilus, 178
Neanderthal Man, 162, 168, 169
Neo-Darwinism, 15, 230, 240 *et seq.*
Neo-Lamarckianism, 245 *et seq.*
Neolithic, 168

Nereis, 45, 175
Nerve, 33, 35, 184, 185
Nests, 134, 181, 196, 197
Neuters, 116, 121
New Accelerator, The, 128
New Stone Age, 168
New World, the, 152, 153
Newt, 70
Notochord, 58, 186, 210
Nuclear acids, 24
Nucleus, 24
Nymph, 102

OCTOPUS, 49, 75
Oestrus, 200, 203, 204
Old Red Sandstone, 42, 53
Old Stone Age, 168
Old World, the, 155
Olfactory lobe, 188
Oligocene, 42, 43, 158
Orang Utan, 154
Orchid, 106
Order, 27
Ordovician, 42, 43
Origin of Species, 230, 233, 254
Ovum, 174 *et seq.*, 216

PALEOLITHIC, 168
Paleozoic, 42, 47, 49, 51–6, 64, 67, 69, 100, 104
Pallium, 188
Paranthropus, 158
Parasites, 122, 206–10
Parthenogenesis, 109
Passerine bird, 129 *et seq.*
Pasteur, Louis, 230
Pattern in time, 122, Ch. XIII
Pavlov, 194
Pea, 219
Peking, 164, 170
Pelvis, 162
Penguin, 141, 142
Pennsylvanian, 42, 43
Periods, 42, 43
Peripatus, 46
Permian, 42, 43
Photo-synthesis, 22, 65, 67
Phylum, 27
Piltdown Man, 157, 158, 164
Pipe fish, 182
Pithecanthropus, 162, 165, 167
Placenta, 84, 85
Planaria, 36, 37
Plankton, 65
Plant life, 27, 65–7, 79, 105
Platypus, 83
Play, 192, 201
Pleistocene, 42, 43, 149, 160, 167, 170
Pliny, 227
Pliocene, 42, 43
Pollen, 67, 105, 111
Polyp, 34
Porpoise, 93
Portuguese Man-o'-War, 36
Potto, 96
Prehistory of E. Africa, The, 160
Primary Era (*see* Paleozoic)
Primates, Ch. XIV, 202–4
Proconsul, 159
Prometheus, 166
Prosimii, 150
Proterozoic, 42, 44
Prothallus, 66
Protoplasm, 19, 22
Protozoa, 25, 27, 208
Pseudopod, 31
Psyche, 226
Pteradon, 74
Pterodactyl, 94
Pupa, 103

QUARTERNARY ERA, 42, 43,149

RACE, 216, 235
Rackham, Arthur, 55
Radar, 95
Radula, 48
Record of the Rocks, 41
Redshank, 123
Reduction division, 217
Reeve, 143
Regeneration, 30
Releasers, 145, 174, 181
Reptile, 70–80, 125, 190, 198 (*see also* Saurian)
Respiration, 26, 32
Rhinoceros, 87
Rhynia, 67
Richards, O. W., 108
Rivers, 59, 181, 183
Roberts, B. B., 141
Ruff, 143

Russell, Dr. E. S., 245 *et seq.*
Rutting, 200

SACCULINA, 208, 209
Salamander, 70
Saldhana Bay, 168
Salmon, 181
Saurian, 18, 70–80
Scales, 60
Science of Life, The, 31, 81, 122, 208
Scorpion, 46, 68, 178
Sea, the, 26
Sea anemone, 55
—— cow, 93
—— horse, 182
—— lily (*see* Crinoid)
—— lion, 201
—— scorpion (*see* Eurypterid)
—— squirt, 59, 209
—— urchin, 57, 176
Seaweed, 29, 54, 65
Secondary Era (*see* Mesozoic)
Sedimentary rocks, 40
Seed, 246
Selous, E., 139
Sensitivity, 32, 61, 85, 88, 90, 112, 146, 173, 185
Seraphim, 53
Sermon on the Mount, 84
Sex, Chs. XVII and XIX
—— and brain, 191
—— and courtship, 177
—— and evolution, 173 *et seq.*
—— and touch, 89
—— in baboons, 203
—— in birds, 131, 143
—— in insects, 180
—— in plants, 105
Sex cells (*see* Gametes)
Seymouria, 74
Shaw, G. B., 242, 254
Sherrington, Sir Charles, 128, 253
Shrew, 96 (*and see* Tree Shrew)
Sight, 22, 50, 61, 89, 119, 150
Silurian, 42, 43, 54, 64, 65
Silver fish, 68, 100, 102
Sinanthropus, 158, 164, 170, 172, 212
Sivatherium, 171
Skin, 81
Skull, 60
Sleep, 74
Slime, 19, 25
Slipper animalcule, 174, 185
Sloth, 92, 211
Slug, 176, 177
Smell, 61, 89, 119, 150, 188, 200
Snail, 48, 55, 176, 248
Snake, 79, 198, 239
Snapdragon, 106
Social insects, Ch. X
Social Insects, The, 108
Solo River, 168
Sophocles, 128
South America, 89
Soul, 226, 255
Specialization, 85, 88, 90–5
Species, 27, 227, 233–7
Speech, 98, 156, 194
Speed, 57, 90
Sperm, 174 *et seq.*, 216
Spider, 46, 178, 248
Spider monkey, 98
Sponge, 29, 30, 32, 55
Spores, 66
Sports, 73
Springtail, 100
Squirrel, 201
Starfish, 55, 176, 185
Stegosaurus, 74
Stickleback, 181
Sun, the, 17, 21, 27, 39
Swanscombe Man, 169, 170
Swimming, 52, 57
Symbiosis, 207
Symbolism, 140
Syndoceras, 87
System, 36

TAPIR, 87
Tarsier, 96
Taungs skull, 161
Teeth, 158, 212
Tenerfine jaw, 172
Tennyson, 205
Termite, 117 *et seq.*, 207
Terra del Fuegans, 231
Terrapin, 79
Territory, 131–3, 137, 177
Tertiary Era (*see* Cainozoic)
Thalamus, 188
Thermostasis, 74, 80–2, 91, 190, 191, 199, 201
Tiger, 92, 110
Tigger, 26

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Time scale, 18, 42
Tinbergen, N., 139
Tissue, 36
Tits, 123
Toad, 70
Tools, 98, 156, 168, 171
Tortoise, 79
Touch, 89, 119
Tracheae, 68, 99
Tree shrew, 88, 95, 96, 150, 205
Trends of Life, 252
Triassic, 42, 43, 73
Trilobite, 18, 51, 55, 72
Tropism, 185
Tunicate (*see* Sea Squirt)
Turtle, 79
Twins, 223
Tyrannosaurus, 74

Ultra-Violet Rays, 73
Ungulates, 87, 91
Use and disuse, 229, 239

Vegetable Life (*see* Plant Life)
Vertebrate, 48, 57, 89, 187, 237
Victoria, Lake, 160, 171
Virus, 25, 207, 252
Vitalists, 16, 245 *et seq.*
Volvox, 28, 237

Walrus, 201
Walter, W. Grey, 69, 185, 190
Warm-bloodedness (*see* Thermostasis)
Wasp, 108 *et seq.*
Weismann, A., 242
Wells, C. P., 31
Wells, H. G., 31, 128, 211
Whale, 93
Widgeon, 123
Wiedenreich, F., 164
Windmill girl, 70
Wings, 79, 100, 111, 237, 238
Winkle, 248
Wishing Well, 91
Wood Jones, Prof. F., 245 *et seq.*
Worm, 36, 37, 185, 186
——, flat, 36, 37, 207
——, marine, 248
——, palolo, 175
——, segmented, 44

X-ray, 222

Young mammals 192

Zoophyte, 27
Zygote, 217, 221, 246

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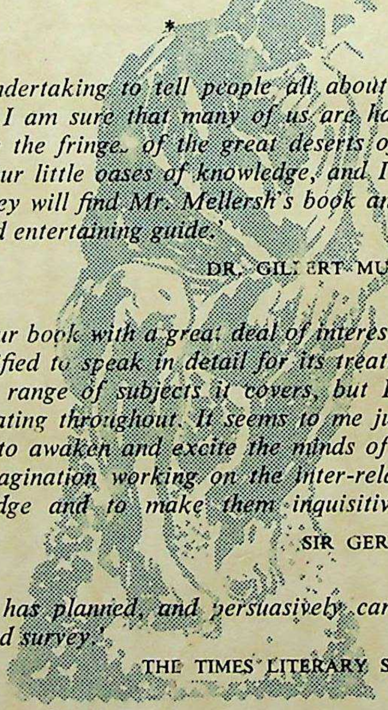

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